In order to estimate the number of adult crocodiles within a 30 km downriver and 10 km upriver distance of the riffle zone spotlight surveys were undertaken in August 2010 and 2011. All spotlight methodology and population estimates were made following the methodology of Webb *et al*. (1987).

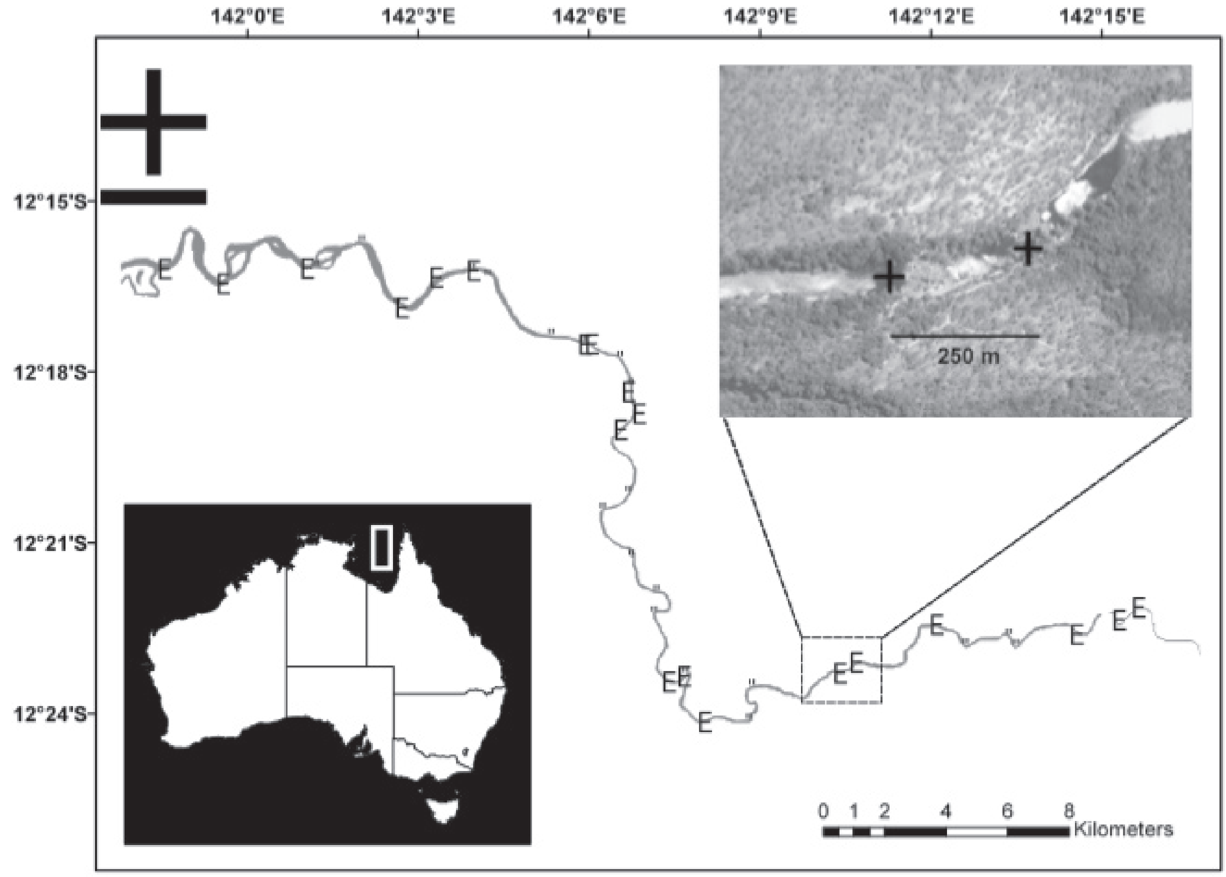

Figure 1. Schematic diagram of the Wenlock River displaying crocodile capture and release locations (black squares) and the location of VR2W underwater listening receivers (black crosses). Inset panels shows study location in Australia (arrow), and overhead image of the shallow water riffle zone (Stones Crossing) with crosses to illustrate the location of each listening station (image supplied by Google Earth©).

Data Analysis

The acoustic transmissions detected upon each of the underwater receivers were used to define periods when the tagged crocodiles arrived and departed the deep pools in the immediate upstream and downstream vicinity of the riffle zone. By comparison of departure and arrival times between the two receivers it was possible to observe the crocodile's movements around and over the riffle zone. All analyses upon the acoustic data were undertaken using the V-track software (written by H.A. Campbell, M.E. Watts and R.G. Dwyer, University of Queensland). These data were then correlated with the tidal, lunar and diel cycles (lunar phase and sunrise and sunset information provided by bureau of meteorology, Australia). The frequency of crocodile movement over the riffle zone was tested for significance against month, hour of the diel cycle, period of the lunar cycle, and hour from the high tide using a one-way ANOVA. P values <0.05 were deemed significant. Probability of crocodile presence within the immediate vicinity of the riffle zone was calculated from the recorded crossing data extrapolated for a projected adult population assessed by spotlight surveys.

Results

Of the 46 adult crocodiles acoustically tagged in the mid to upper section of the Wenlock River in August 2009 and 2010, only 41 were detected to still be within this section of river between September 2010 and August 2011. Out of these 41 adult crocodiles only 12 were recorded in the vicinity of the riffle zone (Table 1). Two of these individuals were captured from the immediate vicinity of the riffle zone, whereas the others were captured and tagged up to 40 km further downstream and 10 km upstream. There was a significant effect of season upon the frequency of crocodile crossings (F1, 10 19.18, $P<0.05$), with a majority of crossings being made between the months of September and December (Fig. 2a). The diel cycle also had a significant effect upon crocodile crossing frequency ($F_{1, 22}$ 32.68, $P<0.01$), and a majority of the crossings were undertaken during the hours of darkness (Fig. 2b). The phase of the lunar cycle had no significant influence ($F_{1, 2}$ 0.334, $P= 0.6$) on the frequency by which the tagged crocodiles moved over the riffle (Fig. 2c), but the stage of the tidal cycle did have a significant influence ($F_{1, 4}$ 44.4, $P<0.01$) upon the frequency of crocodile crossings (Fig. 2d). No crossings were recorded within an hour of the lowest point of the tidal cycle. Upstream movements were focused within 3 hours either side of the high tide, whilst downstream movements were spread more evenly throughout the tidal cycle.

Table 1. Behaviour of acoustically tagged *C. porosus* (mean ± SE) around Stones Crossing between September 2010 and August 2011.

	Upstream	Downstream
Number of crossings	56	60
Number of crocodiles	12	12
Crocodile total length (m)	3.52 ± 0.60	3.52 ± 0.60
Duration of crossing (min)	50.9 ± 1.2	16.9 ± 0.9
Time waiting to cross (h)	9.9 ± 2.5	9.5 ± 5.9

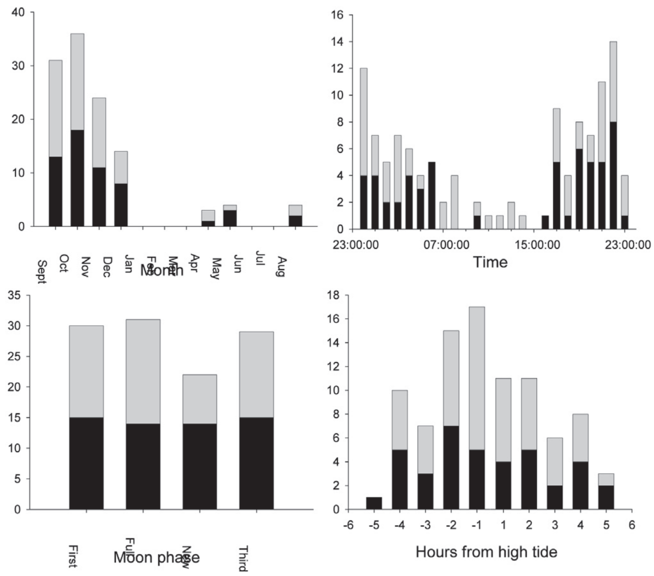

Figure 2. Temporal distribution of riffle zone crossingsundertaken by acoustically tagged *Crocodylus porosus*, separated into downriver (black) and upriver (grey) movements; (a) month of the year, (b) hour of the diel cycle, (c) phase of the lunar cycle, (d) hour pre- and post- high tide.

The acoustic detection data showed that the crocodiles waited for anywhere from 20 min to 36 h in the deep pools in the immediate up and downstream vicinity of the riffle zone prior to crossing (Table 1). The mean length of time that crocodiles would wait in these deep pool areas was similar in duration for upstream or downstream crossings. The time to cross was considerably less than the time the crocodiles spent waiting in the deep pools, and the time to move upstream over the riffle zone took 3-times longer to complete compared to downstream crossings.

The two spotlight surveys undertaken in August 2010 and 2011, counted an adult *C. porosus* population (>2.5 m), within the mid to upper section of the Wenlock River (50 km river length), of 42 and 48 individuals. Combined mark and recapture, helicopter, and boat spotlight surveys have demonstrated that crocodile numbers are underestimated by 35 to 66% from spotlight surveys in mainstream river sections (Bayliss *et al.* 1986). Therefore, we conservatively estimate that the adult crocodile population (>2.5 m) within this section of river to be 100 individuals. Using this population estimate, we calculate that 46% of these individuals were acoustically tagged during the study, with 41% being present between September 2010 and August 2011. Extrapolation of the number of tagged adult crocodiles recorded crossing the riffle zone up to the estimated number of adult crocodiles within the river increased the number of adult crocodiles which crossed over this riffle zone between September 2010 and August 2011 (Table 2). Calculation of the probability of a crocodile being present in the immediate vicinity of this riffle zone, based upon the proposed number of crocodiles crossing over the riffle zone and the average waiting time, showed that there was a higher probability than not of a crocodile (>2.5 m total length) being present (Table 2).

Table 2. Estimates for crocodile presence at Stones Crossing between September 2010 and August 2011. Crossing data were extrapolated up to an adult *C. porosus* population of 100 individuals within the mid to upper section of the Wenlock River.

	Upstream	Downstream
Number of crossings	136	146
Number of crocodiles	29	29
Probability of crocodile presence	0.17	0.21
Probability of crocodile presence between Sep and Dec 2010	0.51	0.65

Discussion

The study findings provide some insight between the behaviour of *C. porosus* around shallow water riffle zones and the incidences of unprovoked attacks upon humans. Firstly, the acoustic tracking data showed that adult Estuarine Crocodiles preferred to cross the shallow riffle area in the dark and on the highest part of the tide, and this resulted in them spending prolonged periods in the immediate vicinity of the riffle zone. These shallow water riffle areas receive a higher proportion of human visitors than other river locations because they form a natural crossing point, are picturesque, good for fishing, and are even considered to be 'safe' swimming locations. The behaviour of humans and estuarine crocodiles around these shallow water riffle areas is conducive with the fact that the majority of crocodile attacks are upon people in the water, wading, or at the water's edge (Caldicott *et al*. 2005). Secondly, the results demonstrated that there was a high probability of a crocodile being in the immediate vicinity of the riffle zone between the months of September to December. These are also the favoured months for camping and fishing within crocodile country, and consequentially, these months have a higher occurrence of human attacks from Estuarine Crocodiles than at other periods of the year (Caldicott *et al*. 2005). Thirdly, 70% of attacks occurred during daylight hours (Caldicott *et al*. 2005). This is most likely a reflection of human activities but may also be a reflection of the crocodile's presence within the close vicinity of riffle zones during daylight hours, as they wait until darkness to cross.

The purpose of the estuarine crocodiles moving across the riffle section is presumably to access habitats along the river. The high frequency of crossings between September and December coincides with the breeding and nesting season (Webb and Manolis 1989), and it is likely that the males increase their range of movement to find mates and the females move to locate nest sites. Previous studies have shown that these months do show the highest annual rate of *C. porosus* spatial movement and trap capture rate (Kay 2004; Walsh and Whitehead 1993). The present study recorded no Estuarine Crocodiles moving over the riffle area between January and March. A possible reason for the absence of *C. porosus* during these months was high flood waters, enabling the crocodiles to travel up and down the river without moving directly over the riffle zone. The very low number of crossings between March and August is perhaps a reflection of the decline in the spatial movement of *C. porosus*.

The tagged estuarine crocodiles in our study showed a preference for crossing the riffle zone during darkness and when the river level was at its highest. These environmental factors would have facilitated a quick crossing with the least amount of exposure for the crocodile. This behaviour suggests wariness by the crocodile, presumably towards humans. Shy behaviour was further demonstrated by the absence of daylight sightings in the vicinity of this riffle zone, even though the acoustic telemetry data confirmed adult estuarine crocodiles were present (H.A. Campbell, pers. obs.). The lack of crocodile attacks at this riffle area, despite the high probability of humans and crocodiles being in the water at reasonably close proximity, supports a theory that Estuarine Crocodiles do not attack humans whenever the opportunity presents itself. Nevertheless, the incidence of human-attacks in Australia by the Estuarine Crocodile demonstrates that this species poses a significant threat to humans. In rivers inhabited by Estuarine Crocodiles we recommend a greater level of awareness around natural weirs and shallow water riffle sections, even if crocodiles have not been recently sighted. Furthermore, we strongly recommend that deeper pools in the vicinity of shallow water riffle zones not be entered and extreme care taken at the water's edge. The shallow waters within the riffle zone may have a low chance of crocodile presence during the hours of daylight, but crocodile presence within these areas will be significantly elevated with the onset of darkness, particularly around the high tide, and between September and December.

Acknowledgements

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People's Attitudes towards the Reintroduction of the Philippine Crocodile in Dicatian Lake

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Abstract

In July 2009, 50 captive-bred Philippine Crocodiles were reintroduced in Dicatian Lake in the Northern Sierra Madre Natural Park on Luzon. Twenty-two months after this pilot reintroduction we conducted a survey in barangay Dicatian to assess people's perceptions on and attitudes towards the reintroduction of the species. There have been several incidents of crocodiles attacking livestock. However a large majority of the people in the village of 77% still supports the reintroduction of the species in the lake.

Introduction

Reintroducing a species into the wild is one of the most challenging activities for conservationists. The endemic Philippine Crocodile *Crocodylus mindorensis* is categorized as Critically Endangered on the IUCN Red List (IUCN 2012). Hunting, the use of destructive fishing practices and the conversion of freshwater wetlands has led to the disappearance of the species in most parts of the Philippines. The Philippine Crocodile now only survives with certainty in southwestern Mindanao and northern Luzon (van Weerd 2010). The primary objective of the national recovery plan for the Philippine Crocodile is to re-establish Philippine Crocodile populations in the wild (Banks 2005).

The Palawan Wildlife Rescue and Conservation Centre (PWRCC) has successfully bred the species, and now maintains more than 700 individuals in captivity (Ortega 1998). Several areas were identified as potential sites where these animals could be reintroduced into the wild. But antagonistic attitudes of rural communities towards crocodiles have hampered these efforts. People fear that the species will attack children and livestock, and consider restrictions on fishing and farming in areas where crocodiles would be reintroduced illegitimate. For example, local government officials and rural communities opposed the plan to release the species in Manguao Lake on Palawan in 1991 (Ortega 1998). Since then, the idea that rural communities oppose the reintroduction of the Philippine Crocodile has dominated conservation policy in the Philippines (van der Ploeg *et al*. 2011). Recently, the Secretary of the Department of Environment and Natural Resources (DENR), Raul Paje, said that 'there is no mayor anywhere in the Philippines who would allow the release of crocodiles in his municipality.' (AFP 2011).

Since 1999 the Mabuwaya Foundation has worked with local government officials and rural communities to conserve the Philippine Crocodile in the municipality of San Mariano in Isabela Province (van der Ploeg and van Weerd 2006; van der Ploeg *et al*. 2011). These experiences resulted in a project to reintroduce captive-bred Philippine Crocodiles in Dicatian Lake in the Northern Sierra Madre Natural Park. After a series of community consultations, the Dicatian village council and the municipal government declared Dicatian Lake a Philippine Crocodile sanctuary. Fifty captive-bred sub-adult Philippine Crocodiles from PWRCC were reintroduced into Dicatian Lake on 31 July 2009 (van Weerd *et al*. 2010).

The reintroduction took place with the agreement of the community and endorsement of the Local Government Unit of Divilacan and the Protected Area Management Board of the Northern Sierra Madre Natural Park. This paper aims to survey people's attitudes towards the reintroduction of the Philippine Crocodile in Dicatian Lake.

Methods

This study was conducted in barangay Dicatian in May 2011, 22 months after the reintroduction of the 50 captive-bred Philippine Crocodiles. We interviewed 100 respondents from the total population of 328 inhabitants. Using the profile of the barangay, we picked every third person (with a minimum age of 8 years). We interviewed each respondent personally with a structured questionnaire (Appendix 1).

Study Area

Dicatian Lake is located within the Northern Sierra Madre Natural Park (NSMNP), the largest protected area of the Philippines. Barangay Dicatian in the Municipality of Divilacan has a total land area of 3270 hectares. It is bounded in the north by Kabicawan cove, in the south by the Dicatian River, in the East by Divilacan Bay, and in the West by the Sierra

Madre mountain range. The terrain is moderately flat along shorelines and relatively rolling at the southeast portion, and mountainous to very steep sloping towards the west. The flat areas are covered with rice fields and coconut plantations. Most of the land in barangay Dicatian is privately-owned.

A dam in Dicatian Creek was constructed by the Department of Agriculture (DA) and the Local Government Unit (LGU) of Divilacan in 1998 for irrigation purposes. The dam submerged the small creek and part of the forest and created a lake. The surface area of the lake is 14.9 ha and the perimeter is 3601 m. A small Philippine Crocodile population survived in the lake. Accidental killings led to the extinction of the species in the lake in 2005. After a series of community consultations the village council of Dicatian and the municipality of Divilacan declared the lake as a Philippine Crocodile sanctuary on 1 March 2009 followed by the reintroduction of the 50 captive-bred sub-adult Philippine Crocodiles on 31 July 2009.

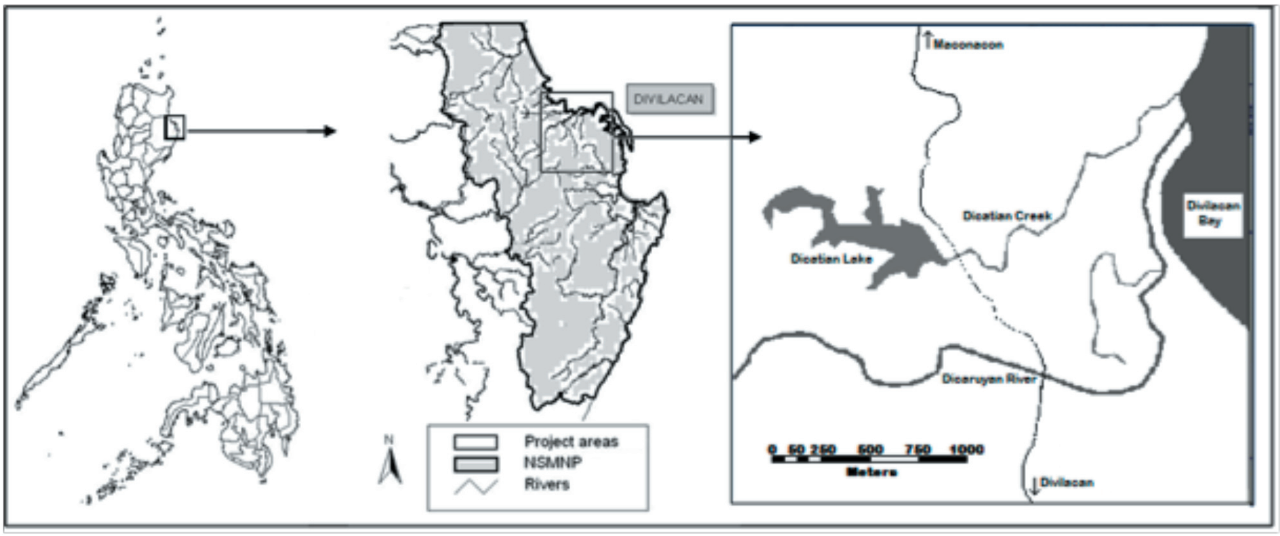

Figure 1. (left) Location of Divilacan within the Philippines and Northern Sierra Madre Natural Park (NSMNP); (right) location of Dicatian Lake and village in Divilacan.

Results

79% of the respondents said that they were informed about the project prior to the reintroduction. Some of the respondents were not around during the community consultations that preceded the reintroduction. 71% agreed with the fact that crocodiles were reintroduced, also 22 months after the reintroduction, but 42% were not aware why the crocodiles were actually reintroduced in the lake.

Forty-eight percent of respondents in barangay Dicatian claim that they have been negatively affected by the reintroduction of the Philippine Crocodile in the lake (Fig. 2). Most of these respondents (30%) refer to crocodile predation on livestock, mainly chicken and ducks. Others claim that the reintroduced animals destroyed their rice fields, or that they are now afraid to go near the lake. 52% of the respondents did not have negative experiences as a result of the crocodile reintroduction.

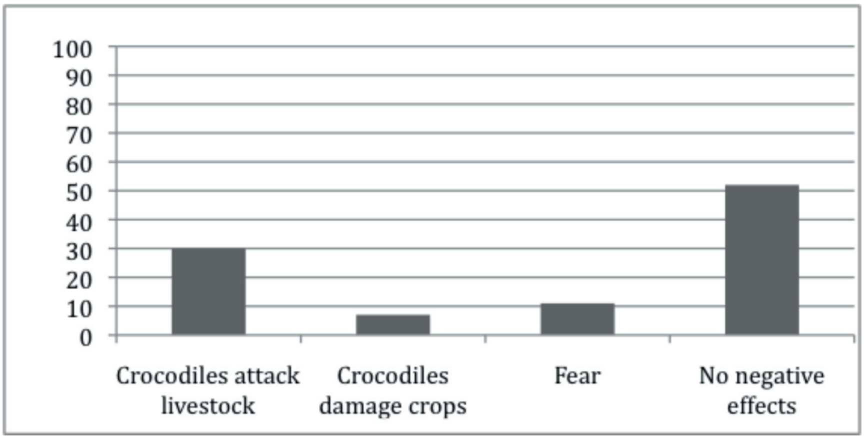

Figure 2. Proportion of respondents affected by the reintroduction of the Philippine Crocodile in Dicatian Lake in terms of livestock predation, damage to crops, fear to go near the lake and no negative effects.

Despite the fact that almost half of the respondents feel they have been impacted negatively, a majority of the respondents (57%) said that they have also benefited from the crocodile reintroduction (Fig. 3). They generally refer to the support by the Mabuwaya Foundation to the community; Mabuwaya assisted the barangay to purchase a generator for general use in the village centre, trained villagers to set up small-scale eco-tourism enterprises and helped individual fishermen with training and gear to shift from fishing in Dicatian lake to fishing at sea or to construct fish ponds. After Super typhoon Megi devastated the coastal area of Isabela Province in October 2010, Mabuwaya started an international aid campaign to help Dicatian and other coastal communities to rebuild infrastructure such as schools and day-care centres.

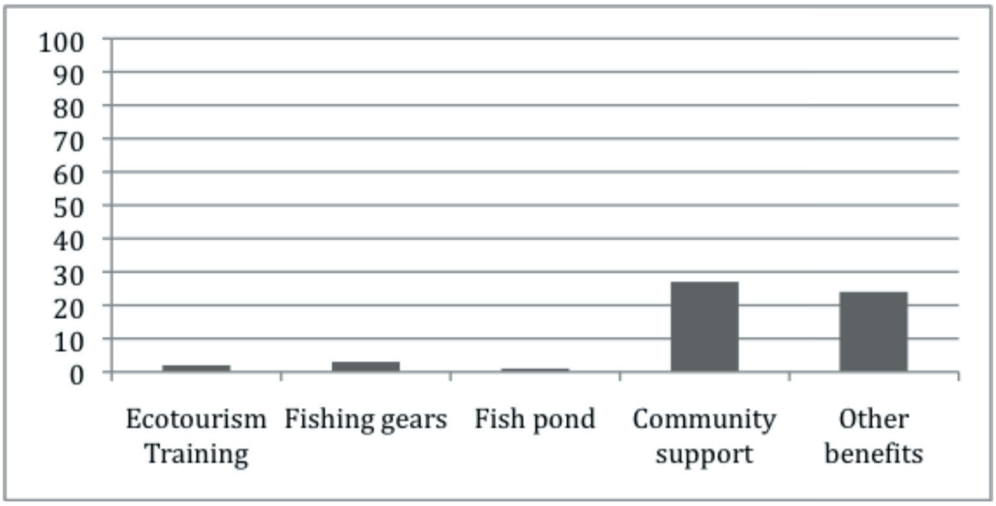

Figure 3. Proportion of respondents that say they benefitted from the reintroduction of the Philippine Crocodile in terms of community and household support.

Crocodile attacks on livestock are widely regarded as the biggest problem by the community (Fig. 4). Other identified problems are the damage crocodiles do to freshly planted ricefields, the fear some people have to approach Dicatian Lake or the fear that their children will be attacked by a crocodile, the damage inflicted to fishnets if crocodiles become entangled in them, crocodiles leaving the lake and the fact that fishing is now prohibited in the Dicatian Lake Philippine Crocodile sanctuary. 37 respondents (37%) do not identify any problem with the crocodiles.

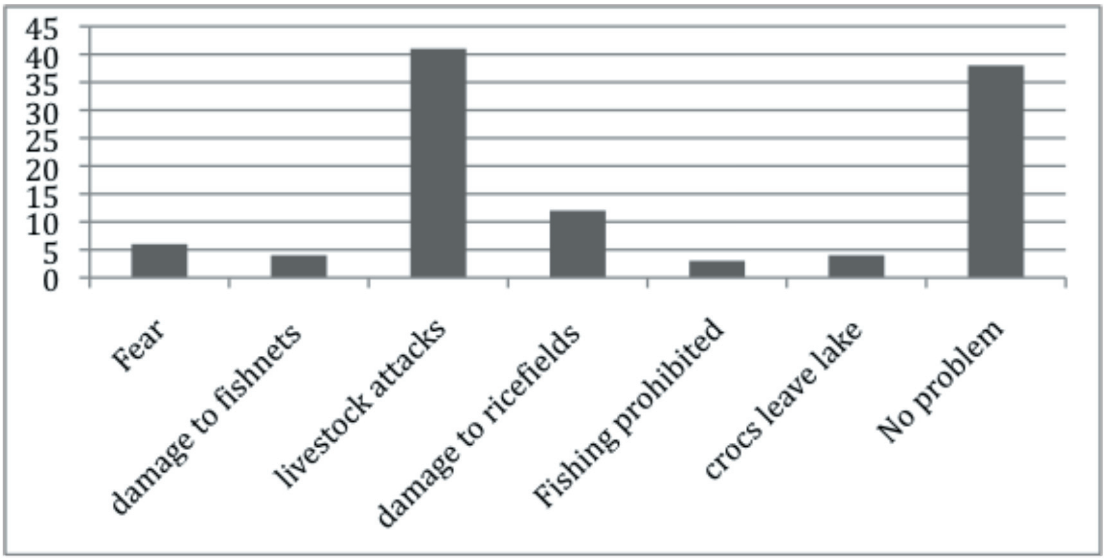

Figure 4. Number of answers to the question: what are the most important problems with the crocodiles in Dicatian? (multiple answers possible).

Many respondents (50) suggest fencing the lake to prevent further attacks on pigs, ducks, chicken and dogs. Other solutions put forward are to remove the crocodiles from the lake (6), provide alternative livelihood assistance to people suffering negative impacts by the crocodiles (6), educate people on the importance of crocodile conservation and on how to avoid problems with crocodiles (5), guard the crocodiles so they will not leave the lake or attack livestock (3) and compensate people for livestock losses (2). 37 respondents do not think the crocodiles form a problem for which solutions are needed (Fig. 5).

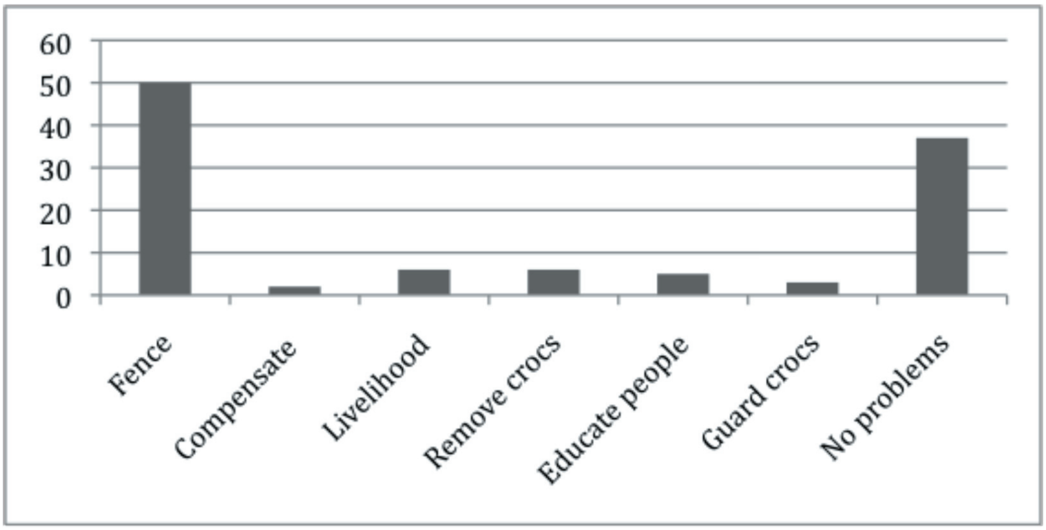

Figure 5. Number of answers to the question: how can we solve the problems with crocodiles in Dicatian Lake?

Discussion

The majority of people in Dicatian (77%) still support the reintroduction of crocodiles in Dicatian Lake but crocodile attacks on livestock do erode local support for the reintroduction. The animals that were released had been in captivity for seven to ten years at PWRCC, where they were fed with chicken and fish. Habituation to people could have caused the crocodiles to come near human settlements and attack livestock. It was observed that most released crocodiles had difficulties in catching their own food, despite the abundance of prey in Dicatian Lake (Mabuwaya Foundation 2009). Farmers and local government officials suggest fencing the lake to minimize crocodile attacks on chicken, ducks and dogs. However, the goal of the reintroduction is to establish a wild Philippine Crocodile population in the Northern Sierra Madre Natural Park, a large protected area (280,000 ha land area) established to conserve free-roaming wildlife. Nevertheless, a partial fence (for example on the dam) could give people a sense of security, and indicate that the concerns of the people are taken seriously. Setting up a compensation scheme or a livestock protection program (for example constructing pig pens and chicken houses so animals are safe at night) are other options to deal with crocodile-livestock conflicts. The finding that many people do not know why crocodiles are released into the wild highlights the need for continuous environmental communication and education.

The findings of this study have important implications for the efforts to re-establish Philippine Crocodile populations in the wild. Antagonistic attitudes towards crocodiles by rural communities and local governments do not form an insurmountable barrier to the reintroduction of the species. With intensive environmental communication and education these negative perceptions and attitudes can be changed into active support for the conservation of the species in the wild. The fact that 50 captive-bred Philippine Crocodiles were reintroduced with full consent of the community and municipal government offers hope that the species can be reintroduced in other areas of its historical range. It remains imperative though to monitor human-crocodile conflicts after reintroduction and to provide solutions to conflicts.

Acknowledgements

We would like to thank all respondents in Dicatian, the community and the Barangay Captain and Council members of Dicatian, Mayor Bulan and the local government unit of Divilacan, Protected Area Superintendant William Savella and Resti Antolin of the Department of Environment and Natural Resources Region II. The Philippine Crocodile reintroduction project in Dicatian and this interview study have been made possible by a Grant provided by the Rufford Foundation.

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Appendix 1. Questionnaire on the attitudes of local people after the reintroduction of crocodiles in Dicatian Lake.

1. Name:

2. Sex: Male Female

3. Age:

4. Education:
Elementary level / Elementary graduate
High school level / High school graduate
College level / College graduate

5. Ethnicity: Ilocano Ibanag Agta Kalinga Other ....

6. Livelihood: Farming Fishing Trade Official Other ....

7. Were you informed about the reintroduction of crocodiles in Dicatian Lake? Yes No

8. Did you agree that crocodiles were reintroduced in Dicatian Lake? Yes No

9. Do you know why crocodiles were reintroduced in the lake? Yes No Don't know
If yes: Why? To protect the species
To develop ecotourism
Other reason ....

10. Were you negatively affected be the reintroduction of crocodiles? Yes No
If yes: How? Crocodile attack on livestock
Damage to fish net
Damage to agriculture
Fear
Loss of access to the lake (fishing)
Other damage ....

11. Have you benefited from the re-introduction of the Philippine crocodile? Yes No
If yes: How? Ecotourism training
Fishing gear
Fish pond
Support to the community
Other ....

12. Who is responsible for the protection of the crocodiles?

DENR	Mabuwaya Foundation	Barangay council
LGU	Bantay Sanktuwaryo	Community
Other	....	

13. What is the most important problem with the reintroduction of crocodiles?

Crocodiles attack people	Crocodiles attack livestock
Crocodiles damage fishnets	Crocodiles damage rice fields
Crocodiles leave the lake	Other ....
People kill crocodiles	

14. How can we solve this problem?

Fence the lake	Remove the crocodiles
Compensate people	Educate people (training)
Provide livelihood support	Disseminate information
Other	

15. What is your overall feeling about the reintroduction of crocodiles in Dicatian Lake?

A Preliminary Analysis of Worldwide Crocodilian Attacks

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Abstract

Attacks on humans by crocodilians have been documented reasonably well in developed countries in the last few decades. Conversely, attacks in developing countries are typically poorly documented despite those countries holding the highest frequencies of crocodilian attacks. Here we present the results of an analysis of over 600 crocodilian attacks worldwide for the period of 2008 through 2011. Attack data were compiled from a number of sources including online media reports, local wildlife officials, crocodilian experts, and relevant recent publications.

Introduction

Human wildlife conflict is a serious and developing issue (Distefano 2008), but understanding and mitigating such conflict requires an understanding of the scale of the problem and the variables involved. This is where databases allowing analysis and interpretation of existing data can have value as a conservation and management tool. For crocodilians this is particularly relevant for developing regions where attacks can be frequent due to water use practices and lack of management (Lamarque *et al*. 2008), and reporting practices from such areas are often incomplete. International media rarely cover attacks in poorer regions, local media may not archive such attacks, government agencies may be wary of reporting and recording data, and misleading impressions about the levels of wildlife conflict can result. Lack of management is often compounded by widespread retaliatory killings of crocodilians (eg Bangka-Belitung Islands in early 2012; Satriawan 2012) that risk local extirpation.

Regions in which crocodilian attacks are common are often those in which crocodilian awareness education is limited and habitat destruction is high, leading to inevitable conflict between humans and crocodilians (eg Sumatra, Borneo). Knowing which regions are experiencing high attack frequencies can guide the implementation of preventative measures such as constructing crocodile-proof barriers along crocodilian-inhabited waterways that are used by humans on a frequent basis, as well as initiating crocodilian education programs and erecting signs warning of crocodilian presence along waterways. An up-to-date attack database can also provide useful information regarding crocodilian presence within areas that have not been surveyed in decades (ie East Nusa Tenggara of Indonesia, Tanintharyi State of Myanmar) and highlight changing attack trends throughout the range of each species over time. Lastly, in addition to procuring useful information regarding human activities associated with attacks, we also gain valuable insights into species-specific differences in attack behaviour on humans, such as those that primarily attack defensively versus those that may regard humans as potential prey.

Materials and Methods

Our database is comprised of four parts: (1) the raw database itself presented within an Excel spreadsheet; (2) a Word document providing detailed descriptions of each attack; (3) an interactive Google Map showing approximate attack locations for every data point; and, 4) a more detailed analysis and comparison of trends within the database. Our aim is to archive this database and provide free access for research, management and educational purposes.

The database of attacks is compiled from a combination of online news reports in different languages, information provided by local wildlife officials/crocodilian experts including existing attack data compilations, and relevant publications. Each attack is reviewed for accuracy, particularly in the case of online news reports where errors and exaggeration may be expected, and entered into the Excel database with as many variables as can be derived from the source. Each attack is also given a broad quality rank depending on its likely veracity, typically depending on the source and whether or not that attack is corroborated by local officials. Each attack is also given a latitude/longtitude coordinate to allow it to be plotted onto a Google Map, the accuracy of which will depend upon the source.

The database is to be presented on a dedicated website which will allow the database to be searched using any of the variables available. The output from each search will be available to view in tabular and text formats, and the relevant data points presented on a Google Map. The ability of the general public to download the raw data is still to be determined but the intention is to prioritize CSG member access to the data.

Results and Discussion

There are some obvious issues with our current database and with obtaining crocodilian attack data in general. First and foremost, there are clear "blind spots" in the data for regions from which attacks are not reported to the media and, in some instances, may go unreported entirely. We also must take into account the veracity of media reports (which constitute the majority of our current database) and the obvious loss of online news records over time, leading to the false impression that attack frequency is increasing at substantial rates. Sensationalism and over-exaggeration within the media are other issues - the circumstances of an attack and the size of the attacking crocodilian are often blown out of proportion.

Despite this, there are clear benefits to the maintenance of such a database. Media will always seek "attack data" for stories on crocodile attack incidents, and controlling the flow of information and directing the way users access it is preferable to a less controlled approach where media may access inaccurate, biased and misleading information and interpretations of such. Loss of attack data are also of concern if any kind of analysis of trends is to be attempted, and such a database can play an important role in archiving these data for future interpretation. There is clearly a need for continual updating of such a database, and the question of what will happen if and when there are no personnel available to continue to update this database are relevant, but by opening the process up to the CSG community it is hoped that contingency measures through multi-user participation will become an option if the database proves to be a valuable asset.

The ability to monitor trends and see unpredictable patterns in attack data provide one of the most important roles for such a database, a role that may not be immediately obvious until the database becomes more complete, but such is the nature of a large amount of data. Our preliminary analysis has been broken down by species and has revealed some interesting information:

<u>Saltwater Crocodile (*Crocodylus porosus*)</u>: The analysis suggests that this species is responsible for considerably more attacks on humans than previously believed, likely due to the majority of attacks being reported in different languages or only to local media. The known major conflict regions are Sumatra, East Kalimantan, Timor-Leste (East Timor), Sri Lanka and Bangka-Belitung; a few attacks are also reported annually from East Nusa Tenggara and Sulawesi. The data suggest that in recent years attacks have also been on the rise within the Andaman and Nicobar Islands. Attacks on Little Andaman have been documented (Whitaker 2008), but in recent years attacks within Middle and South Andaman have been on the rise, while attacks within the remote Nicobar Islands may go unreported (Manish Chandi, pers. comm.). It is believed that attacks are also frequent within New Guinea and the Solomon Islands, but reports to the media are infrequent. World Wildlife Fund (WWF) has stated that attacks are also quite common within the Sundarbans of India (The Times of India 2009), yet data regarding these attacks are unavailable. Recent attacks on Lembata Island of East Nusa Tenggara, the Bengkulu Province of Sumatra and West Sulawesi have provided useful information regarding the current distribution of the species, which has been extirpated from much of its former range.

<u>Nile Crocodile (*Crocodylus niloticus*)</u>: Data for this species are severely limited by a lack of media reporting from many countries that are known to have high attack frequency (ie Mozambique, Burundi, Malawi, Ethiopia), leading to the false impression that this species is responsible for fewer attacks than *C. porosus*, which we know is not the case. Recent reports from Uganda (Olukya 2012) and Mozambique (Mucari 2012) suggest that only a small fraction of the attacks that occur are reported by the media. In regards to *C. niloticus* attacks we hope that we can work with African crocodile experts to improve the database for the species and increase its utility.

<u>Mugger Crocodile (*Crocodylus palustris*)</u>: The database suggests that this species is responsible for the third highest number of reported fatal attacks on humans, behind *C. niloticus* and *C. porosus*. What is interesting is that *C. palustris* attacks rarely involve any consumption of the victim and death is often reported to be a result of drowning after the crocodile drags them under. This is in contrast to both *C. niloticus* and *C. porosus*, which are often reported to consume portions of their victims. This suggests that attacks by *C. palustris* are more likely to be territorial/defensive in nature, rather than predatory. Attacks by *C. palustris* have recently been documented in Maharashtra State (Whitaker 2007) and Gujarat State (Vyas 2010). Gujarat State is the site of the highest number of reported fatalities, but attacks have been documented by the media in most Indian range states in recent years.

<u>American Crocodile (*Crocodylus acutus*)</u>: While *C. acutus* is responsible for the highest number of reported attacks within the New World, fatalities are still relatively rare (none reported to the media since October 2010, although 5 fatalities were reported that year). The regions with the highest frequency of *C. acutus* attacks are Mexico, Costa Rica and Panama. Costa Rica holds the highest number of reported fatal attacks, but within the past two years the frequency of attacks has dropped significantly. Attacks have been documented and detailed within both Costa Rica (Bolaños Montero 2011) and Mexico (A.R. Delgado, pers. comm.) in recent years. Information from Panama is limited and attacks may be more frequent there than widely reported (M. Venegas-Anaya, pers. comm.). In addition, no information is available at all from Honduras, which holds a few substantial populations. Like *C. palustris*, attacks by *C. acutus* rarely involve consumption.

Black Caiman (*Melanosuchus niger*): A handful of *M. niger* fatalities have been reported from Brazil within recent years, along with numerous non-fatal attacks. It is known that the species has been responsible for attacks within Guyana (J. Wasilweski, pers. comm.), but we have no data regarding these attacks. The vast majority of attacks by *M. niger* are reported from Amazonas State, Brazil, although fatalities have also been reported from Acre, Rondonia and Amapa. We have no information regarding attacks in Bolivia or French Guiana and only one reported from Peru. Given the remote nature of much of the range of *M. niger* it is likely that many attacks go unreported.

American Alligator (*Alligator mississippiensis*): Attacks by *A. mississippiensis* are recorded by the wildlife departments of each state and are comprehensive. Thus every reported bite is recorded and this has led to high number of minor non-fatal attacks being presented within our database. Many of the reported attacks are provoked and often involve handling; there have been concerns that perhaps such "attacks" should not be logged into the database. Fatal attacks by *A. mississippiensis* are rare (Langley 2005), and at the date of writing there have been no fatal attacks by *A. mississippiensis* recorded since 2007 and only a handful of unprovoked non-fatal attacks are reported every year, mostly within Florida. It would appear that *A. mississippiensis*, while potentially dangerous, does not deserve its occasional reputation of being as dangerous as some of the larger crocodile species or even some of the other New World species (ie *C. acutus* and *M. niger*).

Other Species: Morelet's Crocodile (*C. moreletii*) has been responsible for a surprising number of attacks (and even a couple of fatalities) given its reputation as a relatively non-threatening species. Attacks are most often reported from Tamaulipas State of Mexico, particularly around Tampico and Altamira. This area is heavily populated by humans and appears to hold a reasonably large population of crocodiles. As is the case with most of the other New World species, the fatal attacks rarely involved any consumption, except in the case of small children. The "False Gharial" or Tomistoma (*Tomistoma schlegelii*) was responsible for 3 reported attacks within our study period (all of them fatal.) In all 3 attacks the Tomistoma responsible were very large, and in one case portions of the victim were consumed. Two of these attacks occurred within Central Kalimantan and were well documented in the media, while the third attack took place within the Rokan River of Riau, Sumatra, in 2010. The frequency of attacks on humans by this species is unknown as most attacks by crocodiles within Indonesia are attributed to *C. porosus* unless reason is given to the contrary; they are likely rare. A small number of attacks have also been reported for *Caiman yacare*, *C. crocodilus*, *C. latirostris*, *Crocodylus intermedius*, *C. mindorensis*, *C. siamensis*, and *C. johnstoni*. We have only one fatal attack by a Cuban Crocodile (*C. rhombifer*), occurring within Zapata Swamp in 1995 (T. Ramos, pers. comm.). While considered aggressive, the species is likely too isolated to be responsible for many attacks on humans.

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Conservation and Management Identifying Individual Gharials to Estimate Population Size, and Determinants of Habitat Use in the Chambal River, India

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† In Memoriam

Abstract

Gharial (*Gavialis gangeticus*) ecology is poorly understood and reliable population estimates are unavailable. We photographed Gharials to enable individual identification, and recorded ecological and anthropogenic covariates to identify determinants of habitat use. We demonstrate the feasibility of photographic capture-recapture for estimating Gharial abundance in the wild. Our results suggest sandy banks adjacent to deep pools as the most critical factor affecting Gharial habitat-use, and that Gharials have a low threshold of tolerance for anthropogenic disturbance. We suggest identification of Gharial 'hot-spots' and a reassessment of current reintroduction programs based on our results.

Introduction

The Gharial (Gavialis gangeticus Gmelin, 1789), endemic to the Indian sub-continent, was common in the river systems of Pakistan, northern India, Bangladesh, Myanmar, Bhutan and Nepal. However, they are now restricted to only a few, scattered locations in India and Nepal. The Chambal River population is the largest contiguous and most viable population, and has been the focus of conservation and restocking programs. It has however, in recent times, suffered from increasing disturbances from extractive activities and is under severe threat from hydrological modifications. Between 1997 and 2006, the Gharial population reportedly experienced a 58% drop across its range; and its total breeding population was estimated to be less than 200 individuals, resulting in a status change to Critically Endangered (Choudhury *et al*. 2007). In spite of the Gharials' precarious situation, quantitatively robust population estimates have been lacking, and rigorous studies on the Gharial have been limited. The goal of this study was to reliably estimate Gharial populations, and identify factors influencing habitat use by Gharials in the Chambal River.

Methods

Study Area

The study area comprises a 75-km stretch of the Chambal River, within the National Chambal Sanctuary, between 26°32'22"N, 77°45'30"E and 26°48'37"N, 78°10'18"E (Daburpur Ghat and Sukhdyan Pura Ghat, Madhya Pradesh, India), and includes the river mainstream, mid-channel islands, sand-bars, rocky outcrops and adjacent banks. The study area exhibits straight and meandering channels with a sinuosity index (meander ratio) of 1.47; and passes through the flat terrain of the Malwa Plateau with an average gradient of 0.21 m/km (Jain *et al*. 2007). The area lies within the semi-arid zone of northwestern India (Hussain 1999) and the vegetation consists of ravine thorn forest (Champion and Seth 1968). Much of the landscape has been influenced by a long history of human occupation (Kaul 1962). Evergreen riparian vegetation is completely absent, with only sparse groundcover along the severely eroded river banks and adjacent ravine lands (Hussain 1999).

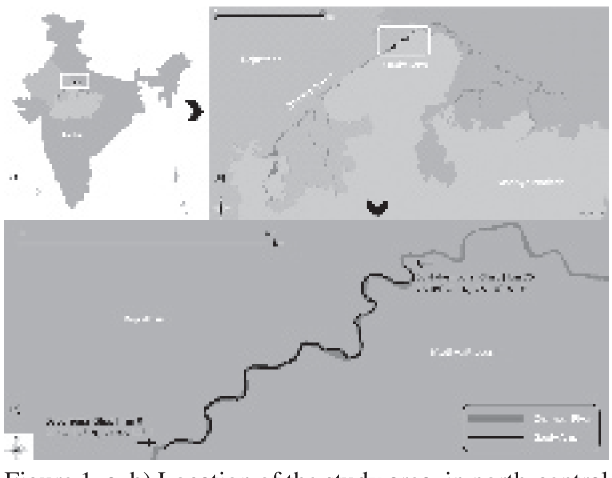

Figure 1. a, b) Location of the study area, in north-central India, along the Rajasthan-Madhya Pradesh border. c) Enlarged map of the study area, showing the 75-km extent of the Chambal River.

In the dry season during the study (February to May 2010), river depth ranged from 0.02 to 18.6 m, while channel width ranged from 44 to 400 m. River discharge levels varied from 75 (February) to 23.9 (May) m^3/s. Sand occupied 29.7% of the shoreline substratum, while gravel, clay-loam and sandstone-rock occupied 16.6%, 20.5% and 33.2% of this stretch respectively. Anthropogenic influences observed during the study period were chiefly in the form of sand-mining, bank-side cultivation, domestic activities like bathing and water collection, gill-net and hook-line fishing, livestock herding, grass-soaking, river crossing and temple fairs.

Field Sampling

The 75-km length of the study area was divided into 30 segments, each measuring 2.5 km, and a rowboat was used to cover this distance in a downstream direction. Four sampling occasions were undertaken between February and May. Each segment was sampled once in February, March, April and May, that is, once in each sampling occasion. Boat survey and stationary bank observations of basking sites were used to collect data. The segments were sampled during periods of maximum basking activity (between 1000 and 1700 h during winter; and between 0630 and 1030 h and 1500 and 1900 h during summer). At each of these basking sites, all basking Gharials were photographed, their location and size-class noted, and basking site characteristics measured. Digiscoping was employed to observe and photograph individual basking Gharials. This was achieved using a 20 - 60x - 80 mm Spotting Scope coupled with a 6 mega pixel digital camera with 3x optical zoom. This was further supported by a 9.1 mega pixel digital camera with 20x optical zoom.

The basic assumptions of closed capture-recapture analysis were met - all individuals had an equal probability of being captured; capture did not affect subsequent recapture; identification marks were not lost; marked and unmarked individuals had the same probability of survival; and geographic and demographic closure.

Habitat variable data like river discharge, water depth, channel width, air and water temperatures, shoreline substratum and presence of basking sites were recorded for each of the 2.5 km segments at a scale of 0.5 km. Anthropogenic activities like sand mining, fishing, bank cultivation, livestock presence, river crossing and miscellaneous activities (bathing, water collection, grass soaking, temple fairs, etc.) were also recorded at the same scale.

Individual Identification and Population Estimation

Individual Gharials were identified by comparing the natural blotches and markings on the lateral scutes of the tail (Singh and Bustard 1976) and also by using additional cues like injuries and scars (Fig. 2; see Nair 2010 for more details). Gharial size-classes were determined by calibrating natural objects or landscape features beforehand, or by setting up measured reference markers at basking sites and then estimating Gharial lengths from photographs using the software 'ImageJ' (Rasband 2007). Individuals <90 cm long were considered to be yearlings, 90-180 cm as juveniles, 180-300 cm as sub-adults, and >300 cm as adults.

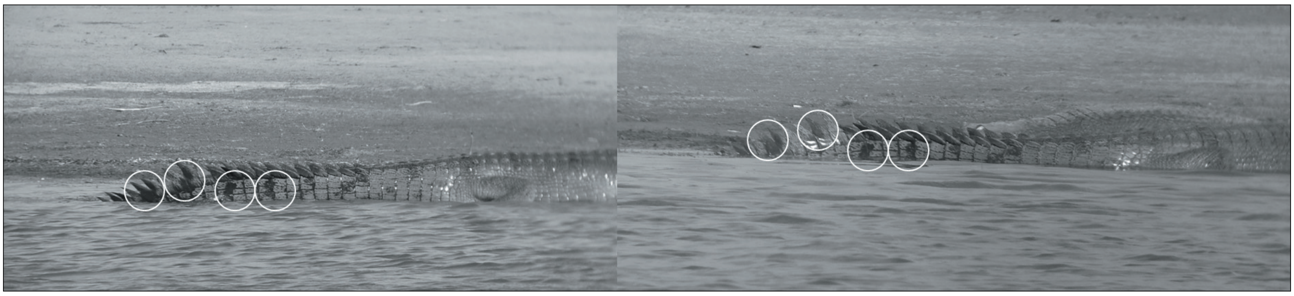

Figure 2. Photo-identification of individual Gharials by comparing the shapes and positions of natural blotches and markings on the lateral scales of the tail.

A standard 'X' matrix (Otis *et al*. 1978) was constructed for identified individuals' inorder to estimate abundance using capture-recapture models. Statistical tests in program CAPTURE (Otis *et al*. 1978; Rexstad and Burnham 1991) supported population closure (z= -1.48, P= 0.069). Closed capture-recapture models were used for abundance estimation in program MARK (White and Burnham 1999). Since individuals may have independent probabilities of being captured on account of their age, size, social status, etc., finite mixture models (Pledger 2000) employing two mixtures of P values, were used to investigate the effects of individual heterogeneity. Here, capture probabilities come from more than one capture probability distribution. There are three parameters with the 2-distribution mixture model - the probability that a given capture probability will come from the first distribution (π), the mean capture probability of the first distribution and the mean capture probability of the second distribution (Pledger 2000).

There was a marked decrease in the intensity of basking, with the progress of the dry-season during the study (Nair 2010). Hence, time was considered an important parameter. Since Gharials are 'thermoconformors', and avoid extreme temperatures (Lang 1987a,b), the number of captures of basking animals are expected to vary from winter to summer. Individual heterogeneity was also considered important since there are differences in accessibility to basking sites, due to social hierarchies; differences in individual responses to disturbances and individual thermal behaviour is known to vary, influenced by a range of internal (age, nutritional status, etc.) and external (social mileau, climate, etc.) factors. (Lang 1987a).

The Akaike Information Criterion (AIC) index of model fit was used for model selection. The model with the lowest AICc score was considered the most parsimonious (Burnham and Anderson 1998). Models with ΔAICc <2 were considered good models (see Table 2), since these models are best supported by the data, while models with ΔAICc between 3 and 7 have moderate support and those greater than 7-10 are relatively poor (Anderson and Burnham 1999; Burnham and Anderson 2002). Estimates of the derived parameters (Burnham and Anderson 2004), from models with good and moderate support (ΔAICc <7), were model averaged in program MARK, to produce an estimate which is conditional on the results from the above selected models.

Effects of habitat and anthropogenic variables

Changes in river discharge and in air and water temperatures during the study were plotted using box-and-whiskers plots. Water depth and channel width were recorded at 0.5-km intervals along the length of the river. In addition, depth measurements were taken at 10-m intervals along the width of the river. Kriging was employed in a Geographical Information System to interpolate these depth measurements. We used scatter plots to ascertain the correlation between various human activities and Gharial encounter rates.

To identify factors affecting the encounter rates of Gharials in each of the segments, we used Classification and Regression Trees (CART) (Breiman 1984). Models with the lowest Residual Mean Deviance and number of terminal nodes (tree complexity) were used, as measures of model selection. Encounter rates were modelled as a function of all habitat and anthropogenic variables. From these, only extent of shoreline substratum, channel width, mean channel depth and the extent of sandstone-rock shoreline substrate were used in the actual tree construction. Numbers at terminal nodes indicate mean Gharial encounter rates influenced by that particular parameter.

Over 80% of our data set consisted of zero-values, that is, a large number of zero Gharial encounters (Fig. 3). These are referred to as 'zero-inflated' data. The zeros of the dataset are treated as Bernoulli outcomes with a probability p0 for the proportion of zeroes in the data, while the non-zeros are treated as having a Poisson distribution.

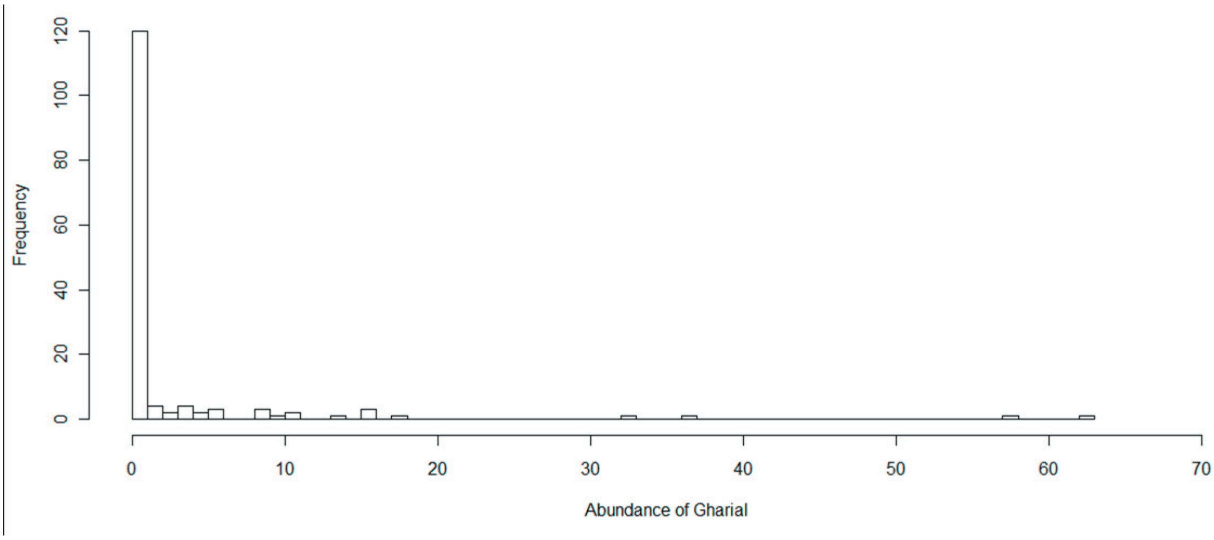

Figure 3. Zero-inflated nature of Gharial encounter rates (abundance).

We used Bayesian spatial count regression models for analyzing the effects of ecological covariates and spatial adjacency on encounter-rates.

For site (i),
Gharial count [i] ~ Intercept + slope * basking site [i] + spatial effect term[i], OR
Gharial count [i] ~ Intercept + slope * depth [i] + spatial effect term[i]

We compared Zero-Inflated Poisson (ZIP) and Zero-Inflated Negative Binomial (ZINB) models, and to these we assumed a Conditional Auto-Regressive (CAR) normal distribution as an uninformative prior distribution for spatial random effects. Deviance was compared for model selection. All statistical analyses were conducted using the software R 2.11.1 (R Development Core Team 2010) and WinBUGS (Spiegelhalter *et al*. 2007). For Bayesian analyses, 10,0000 Markov chain Monte Carlo simulations were carried out and a burn-in period of 10,000 iterations was discarded for each model.

Results

Abundance Estimate

Four hundred captures (332 unique photographs; 159 only left sides, 134 only right sides and 39 both sides) were obtained from the total sampling effort. Capture histories were constructed separately for either side since most captures were obtained of only one side and the side with most captures (left) was used in the analysis (Table 1). Individuals photographed from both sides were also used.

Table 1. Summary statistics for photographic capture-recapture data (left-side only + both sides) of 198 Gharials (114 adults, 37 sub-adults and 47 juveniles) sampled in National Chambal Sanctuary during February-May 2010.

Sampling Occasion	1	2	3	4
Animals caught at occasion	52	69	61	66
Newly caught at occasion	52	61	46	39
Re-caught at occasion	0	8	15	27
Total caught at end of occasion	52	113	159	198

Closed population models and three groups (adults, sub-adults and juveniles), were employed in Program MARK for abundance estimation. Finite mixture models employing two mixtures of P values were used to investigate the effects of individual heterogeneity. Models were selected using the Akaike Information Criterion (AIC) index of model fit (Table 2). Capture probability (p) and recapture probability (c) were modelled as p= c, since the study design did not modify Gharial behaviour across the four occasions, ie, no behavioural effects. Capture probability (p) and recapture probability (c) were modelled either as varying over time (t), constant over time (.), varying across mixtures (g), or varying across both mixtures and time (g+t). The heterogeneity parameter, ie, probability of mixture (pi) and population size (N) were modelled across mixtures (g), to compute independent estimates for adults, sub-adults and juveniles.

Table 2. Model selection by program MARK for Gharial capture-recapture data from the National Chambal Sanctuary during February-May 2010, using AICc, Δ AICc, AICc Weight, Model Likelihood and Number of parameters (k). Heterogeneity parameter, ie, probability of mixture (pi); varying across mixtures (g); varying over time (t); constant over time (.)

Model	AICc	Δ AICc	AICc Weight	Model Likelihood	k
{pi(g), p(g+t)=c(g+t), N(g)}	-482.8165	0.0000	0.38051	1.0000	15
{pi(g), pa(t)= ca(t), pb(t)=cb(t), N(g)}	-482.6898	0.1267	0.35715	0.9386	14
{pi(g), p(.)= c(.), N(g)}	-481.3976	1.4189	0.18718	0.4919	4
{pi(g), p(t)= c(t), N(g)}	-478.5194	4.2971	0.04439	0.1166	7
{pi(g), p(g)= c(g), N(g)}	-477.5535	5.2630	0.02739	0.0720	6
{pi(g), p(g+t), c(g+t), N(g)}	-473.1566	9.6599	0.00304	0.0080	39
{pi(g), pa(g+t)=ca(g+t),pb(g+t)=cb(g+t), N(g)}	-468.8527	13.9638	0.00035	0.0010	30

Models with good and moderate support (ΔAICc <7), were model averaged, to produce an estimate which is conditional on the results of the selected models. Abundance estimates from the most parsimonious models (low ΔAICc) exert most influence to the final estimate. The standard error (SE) of the model averaged estimate is a function of the SE from each model and the extent of compatibility between model-specific estimates (Conn *et al*. 2006). The 'top' model estimated 231±32 adult, 83±23 sub-adult and 89±19 juvenile Gharials respectively, while the weighted average estimated 220±28 adult, 76±16 sub-adult and 93±16 juvenile Gharials respectively.

Determinants of habitat use

Gharial encounter rates and site occupancy are expected to be influenced by seasonality of river discharge and temperature, both of which showed marked changes across the duration of the study. Ambient air and water temperature increased from February to May, and river flow and discharge showed a decrease from 75 m^3/sec to 23.9 m^3/sec during this period.

Scatter plots were used to ascertain the correlation between various human activities and Gharial encounter rates. In the following example (Fig. 4), I have used data from a single occasion for representation. On the X-axis is the proportion of a segment used by various human activities, and on the Y-axis is the Gharial encounter rate within those segments. We see that all these recorded human activities negatively influence Gharial encounter rates, which were always clumped at zero or near-zero values of disturbance.

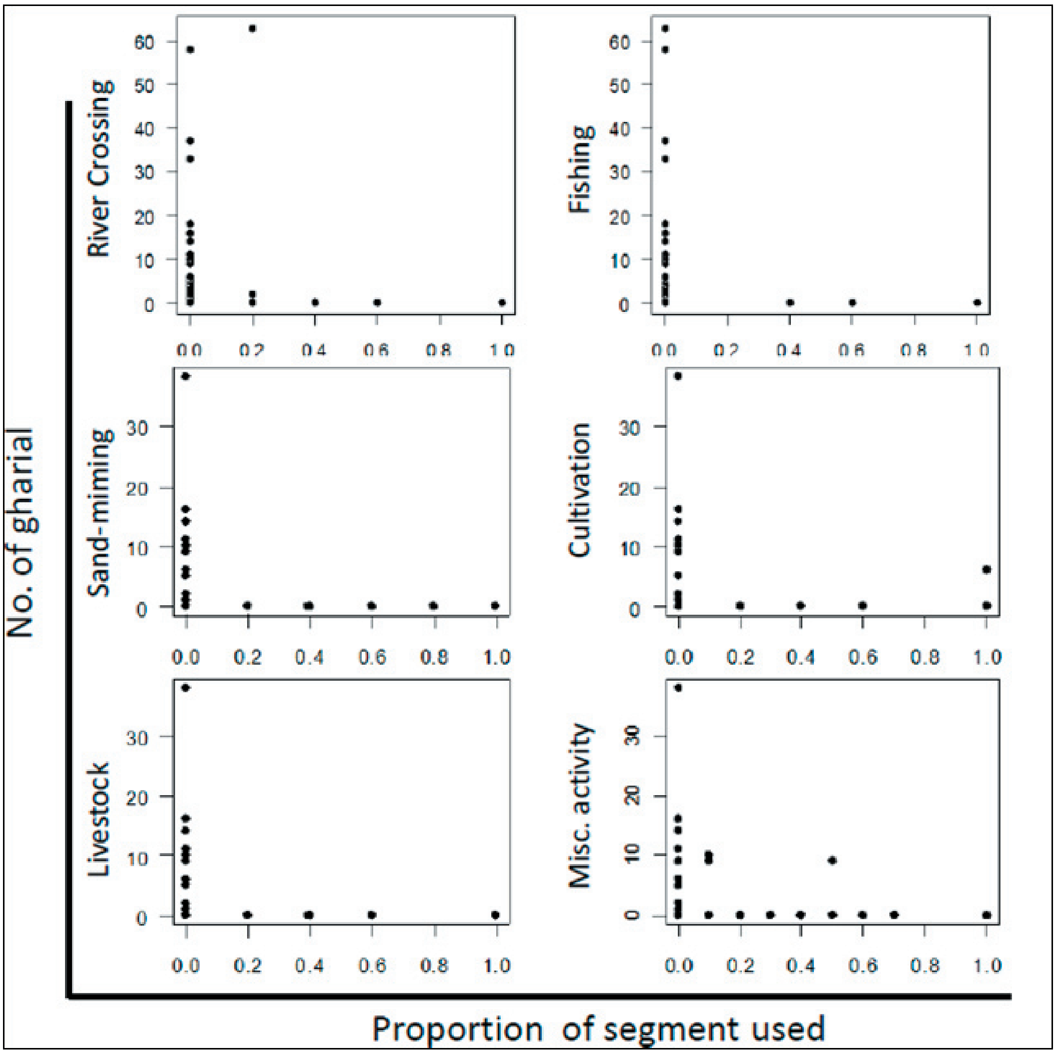

Figure 4. Scatterplots illustrating the correlation between various human activities and Gharial encounter rates.

Classification and Regression Trees were used to identify factors affecting Gharial encounter rates in each of the segments. The following regression tree (Fig. 5) describes the variation in Gharial encounter rates for one occasion. This was the best tree model based on lowest residual mean deviance and number of terminal nodes. Here, heterogeneity within data is hierarchically partitioned such that variation within data is reduced to the extent possible at each split. The influence of a particular parameter on mean Gharial encounter rates is indicated by the numbers (in boxes) at the terminal nodes. In this regression tree the first split at the 'basking sites' demonstrates that the availability of suitable basking sites (sand banks) was the most important parameter. Further, subject to the availability of suitable basking sites, and that it covered more than 50% of that particular segment, 'mean channel depth' greater than 1.45 m emerged as the next most important parameter influencing Gharial encounter rates. The next most influential parameter is complimentary to the availability of suitable basking sites, ie, rock-sandstone bank (unfavourable basking site) covers less than 5% of that particular segment.

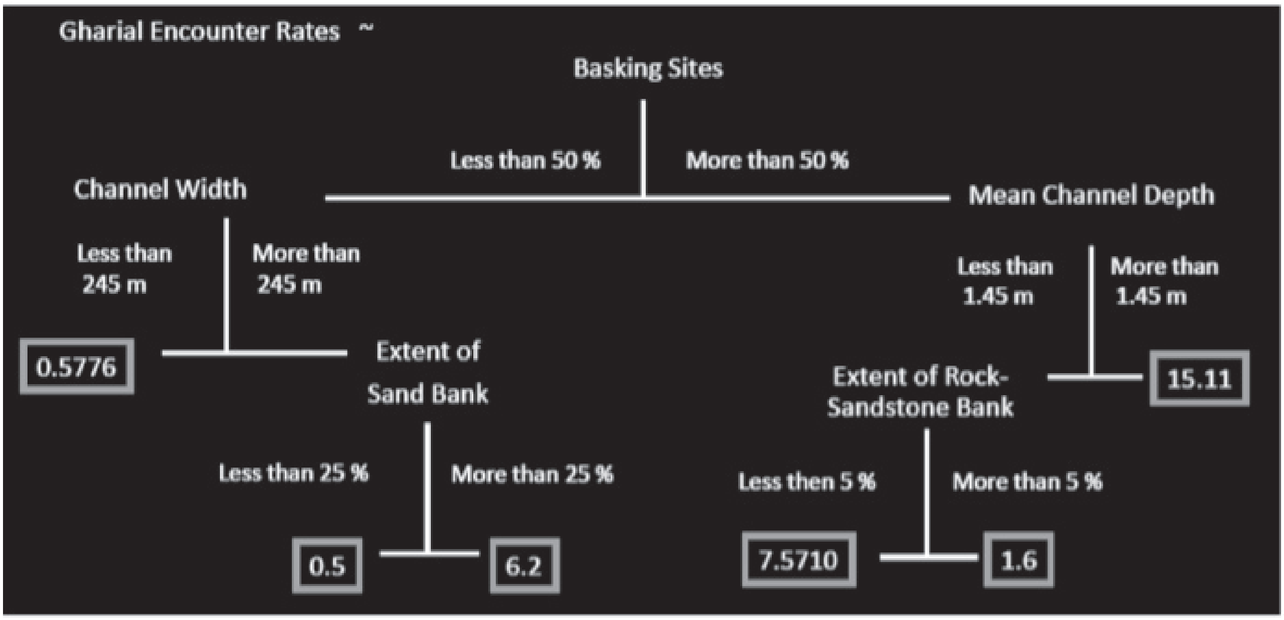

Figure 5. Classification and Regression Tree illustrating the influence of various parameters on Gharial encounter rates in one sampling occasion.

Gharial habitat use positively influenced by presence of basking sites and river depth. Spatial random effect parameter value was low. Zero-inflated Poisson Models were selected over Zero-inflated Negative Binomial Models based on Deviance Information Criteria (Table 3).

Table 3. Parameter estimates for the Zero-Inflated Poisson (ZIP) and Zero-Inflated Negative Binomial (ZINB) models for Gharial encounter rates and habitat usage influenced by basking site and channel depth.

Model	Intercept (beta1)	Slope (beta2)	Spatial Variance (1/tau)	Deviance
~ basking site + spatial effect	Mean (SD) and credible interval	Mean (SD) and credible interval	Mean (SD)	Mean (SD)
ZIP	0.25 (0.47)	1.75 (0.47)	2.1 (0.80)	250 (10.07)
ZINB	0.29 (0.48)	1.73 (0.48)	2.385 (0.95)	250.9 (10.22)
~ channel depth + spatial effect	Mean (SD) ande credible interval	Mean (SD) and credible interval	Mean (SD)	Mean (SD)
ZIP	0.31 (0.60)	0.92 (0.88)	0.85 (0.40)	304.2 (14.82)
ZINB	0.55 (0.54)	0.90 (0.70)	1.09 (0.47)	312.1 (12.61)

Discussion

Population estimation

Our study demonstrates the feasibility of individual identification combined with capture-recapture models to estimate population sizes. Our results also suggest sandy banks adjacent to deep pools as the most critical factor affecting Gharial habitat use, and that Gharials have a low threshold of tolerance for human disturbance.

Our top model estimated 231±32 adult, 83±23 sub-adult and 89±19 juvenile Gharials, while the weighted average estimated 220±28 adults, 76±16 sub-adults and 93±16 juveniles, for our 75-km study area. In comparison, a 2009 survey based on total counts (Bhadoria, Luikham and Sharma, unpubl. data), reported 102 adults, 49 sub-adults and 33 juveniles for a 109-km stretch of the NCS, within which our 75-km study area falls. Based on these values, we estimate absolute densities of adult, sub-adult and juvenile Gharials at 3.08±0.43, 1.11±0.3 and 1.19±0.25 per km. respectively (top model), and 2.93±0.37, 1.01±0.21 and 1.24±0.21 per km. respectively (weighted average). On the other hand, Bhadoria, Luikham & Sharma (unpubl.) estimate densities at 0.94, 0.45 and 0.30 adult, sub-adult and juvenile Gharials per km respectively. Although not accurate or precise, we suggest, on the basis of our 'top' model, a detection probability based correction factor of 3.27, 2.47 and 3.97, to relative abundance estimates of adult, sub-adult and juvenile Gharials, respectively, obtained from boat-based daytime surveys, until such time that better correction factors can be derived.

Conventional crocodilian boat surveys, that rely on total or eyeshine counts, have been shown to underestimate population sizes because of size-related wariness, submergence and concealment bias (Bayliss *et al*. 1986; Hutton and Woolhouse 1989). This, together with the fact that captive-reared Gharial have been released on an ongoing basis in many Indian rivers, has made it difficult to assess the true status of Gharial based on existing population counts (Choudhury *et al*. 2007). Photographic identification of individual Gharial offers several advantages employed within the sampling framework of capture-recapture for estimating detection probabilities and population size. It will also enable regular monitoring of their critically endangered populations. Photo-identification has the advantages of being a non-invasive technique, with fewer economic and logistic constraints of capture, handling, capture and post-capture stress, tracking, altered behaviour and the demand for large sample sizes.

We are also of the opinion that without determining the current status of Gharials, highly intensive strategies like egg-collection and rear-and-release programs, on the basis of underestimates of population sizes are unwarranted and divert valuable conservation resources away from field-based protection measures, which are essential in the face of threats like sand-mining, fishing and bank-side cultivation. Moreover, Gharial reintroductions are poorly monitored, have low success rates (Ballouard *et al*. 2010) and have never re-established viable breeding populations in areas where they were locally extirpated, for all the currently recognised breeding sites had surviving populations when the restocking programmes were initiated (Choudhury *et al*. 2007). Future conservation and management efforts should be based on periodic and rigorous monitoring of demographic and reproductive parameters of Gharial populations and we suggest a reassessment of all reintroduction and restocking programs.

Habitat use

Reduced discharge and water level can mean a reduction in the extent of available habitat, in terms of preferred water depth. Decreasing water levels, through the dry season, was expected to cause increased clustering of individuals, within the deeper sections of the river. However, this did not manifest during the course of this study, probably because the dry season - reduced flow pattern had already set in at the start of the study and the clustering of Gharials observed on all four occasions was an artefact of Gharial response to reduced flow regimes.

The human influences recorded in this study - sand-mining, livestock herding/grazing, bankside cultivation, fishing, river-crossing, and miscellaneous activities, all had a negative impact on habitat use by Gharials. It is possible that mere human presence rather than a particular activity at the land-water interface is the source of disturbance. Gharials displayed a low threshold of tolerance for disturbance and will avoid them. This strengthens the case for having inviolate areas and also for strengthening protection regimes.

Gharial encounter rates and habitat usage were higher in areas where large, undisturbed, sandy banks were adjacent to deep pool sections. While the preference to sandy banks has been attributed to the ease of movement and better basking conditions, deep pools offer suitable refuges from threats (Hussain 2009) and are also known to offer more stable temperature regimes.

The ability to identify, quantify and map the limiting factors for a species will enable the prediction of long-term changes in the behavioural responses and population dynamics of the species, and will also allow the prioritization of conservation areas. For effective conservation and management of Gharials within their natural habitats, it is important to be able to assess species distribution and abundance, and the influence of habitat attributes and human disturbances on them. This is vital to make management recommendations, assess the success and validity of conservation measures, and design future conservation strategies for this critically endangered and charismatic crocodilian.

Acknowledgements

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Gharial Conservation Initiatives in Nepal

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Abstract

Gharial Conservation Initiatives in Nepal is a joint undertaking of WWF Nepal and Department of National Park and Wildlife Conservation, Nepal, funded by "Lacoste". This project has played an instrumental role in bringing about positive impact in Gharial conservation and management in Nepal. Aspects related to long-term gharial conservation has been discussed in this paper. The capacity of 20 wildlife technicians and park staff has been enhanced in scientific monitoring and captive management of Gharials. *Ex-situ* facilities have been improved in Kasara Gharial Breeding Centre at Chitwan National Park. A fish farm has been constructed to supply live fish to Gharials in captivity. Systematic studies have been carried out to establish baseline data with respect to population in wild; quantification of habitat occupancy and threat co-variates. Massive conservation education and outreach program conducted in 27 different locations of Chitwan was influential in changing local people's attitude towards Gharial conservation. Support for 10 fish farms and skilled development training provided to 100 fish-dependent communities as alternative livelihood options in buffer zone areas has helped reducing pressure in Gharial habitats. The population in wild has received pro-active protection with the implementation of smart river rangers' concept in both the Rapti and Narayani Rivers.

Introduction

The Gharial (*Gavialis gangeticus*), belonging to the family Gavialidae, is one of the most threatened of all crocodilian species (GCA 2008). It once thrived in all the major river systems of the Indian sub-continent, spanning from Indus in Pakistan across the Gangetic floodplain to Irrawaddy in Myanmar. Now, it is presumed to be extinct from Bangladesh, Bhutan, Myanmar and Pakistan (Behura and Singh 1978; Maskey 1989). Its distribution is limited only to 2% of its historical range with as few as 200 breeding adults remaining in the wild (Whitaker *et al*. 1974). This represent a 96% decline in the population of this species since 1940s (GSRP 2011). Realizing its grim situation, the Gharial was upgraded from endangered to critically endangered in IUCN's Red Data List in 2007, and is listed in Appendix I of CITES.

In Nepal, the species almost reached the extinction stage during the 1970s. It was revived through captive rearing and restocking program with the establishment of Gharial Conservation Breeding Centre (GCBC) at Kasara, Chitwan National Park in 1978. Since 1992, 861 Gharials have been released in different river systems of Nepal but the wild population hasn't stabilized. Though captive rearing program has been successful; restocking program is very much questionable (WWF 2011) and has only contributed to stop complete extinction in the wild. Presently, the only existing populations are sparsely distributed in the Narayani, Rapti, Babai and Karnali Rivers. In all these river systems, the Gharial faces a grim situation primarily due to tremendous pressure on its food and habitat. Activities like overfishing, use of gill nets, river poisoning, sand mining, and dam construction have together contributed to its periled situation (Maskey 1989; Ballouard and Cadi 2005; Thapalia *et al*. 2009).

Against this backdrop, WWF Nepal in collaboration with Department of National Park and Wildlife Conservation envisioned a project with the long-term goal of "Conserving wild and released gharial population and their habitats by addressing existing threats both through *ex-situ* and *in-situ* approaches". This project has been possible through the generous support of "Lacoste" through Fonds De Dotation Pour La Biodiversite (FDB)'s Save Your Logo Progam (SYL). This project is a 3-year project and receives total funding of 75,000 Euros per annum. It was launched on 7 April 2010 and will continue until 2013. The project so far has been able to accomplish the following objectives.

Objectives

- To establish baseline data on status (population size, density, size classification, adult sex-ratio)and distribution of the species
- To assess the factors governing Gharial presence and quantify threat covariates
- To upgrade the *ex-situ* facilities of the Gharial Conservation Breeding Centre, Kasara
- To build the capacity of the park rangers and wildlife technicians in captive management and scientific monitoring of Gharials.
- To make local communities and the public aware of the plight of Gharials through conservation education and outreach programs
- To integrate favourable measures for Gharial conservation in the management of protected areas
- To collaborate with GCA and reinforce Gharial conservation in Nepal

Study Area

Chitwan National Park: Rapti and Narayani River

The Rapti River forms the northern boundary of Chitwan National Park (CNP). It originates in Mahabharat range and flows for about 120 km before reaching the Narayani River (Smythies 1941; Shankar 1984). It is fed by ground water and springs and hence it does not dry even during the low flow period.

The Narayani River forms the northwestern boundary of CNP. It originates in the Himalayas and is formed by the confluence of the Kaligandaki and Trishuli Rivers. It flows southwest for 30 km from a gorge in Mahabharat range to the confluence with the Rapti River. It then flows for about 25 km while reaching Tribeni and in due course joins the Ganges River in Hajipur, India.

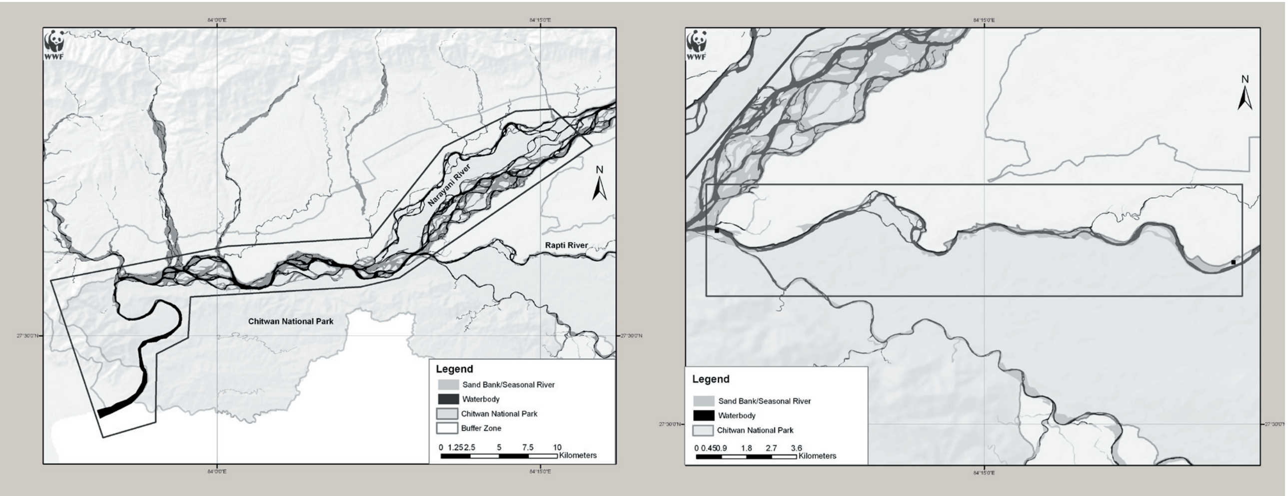

Figure 1. Rapti River (left) and Naryani River (right).

Bardia National Park: Karnali and Babai Rivers

The Karnali River is one of the longest rivers (507 km) in Nepal. It has its origin in the perpetually snow-covered Himalayan mountains [Mansarovar and Rakchas (Demon) Lake]. It receives much snow-fed rivers such as Mugu Karnali and Humla Karnali at the Himalayan belt. On reaching Chisapani the river makes spectacular gorge and diverges into two channels, Karnali in the west and Geruwa in the east. The Geruwa River forms the western boundary of Bardia National Park and flows approximately for 37 km between Chisapani and Kothiaghat.

The Babai River is a tributary of the Karnali River and joins it about 50 km downstream from the Nepal-India border. It originates from a low mountain in Churias at Dang district and flows northwest parallel to the Bheri River. After entering Chepang it remains untouched and locked in from either side of the rivers by mountain ridges. It flows for about 40 km from Chepang to Parewaodar giving a complete scenic beauty to the Babai valley named after the river.

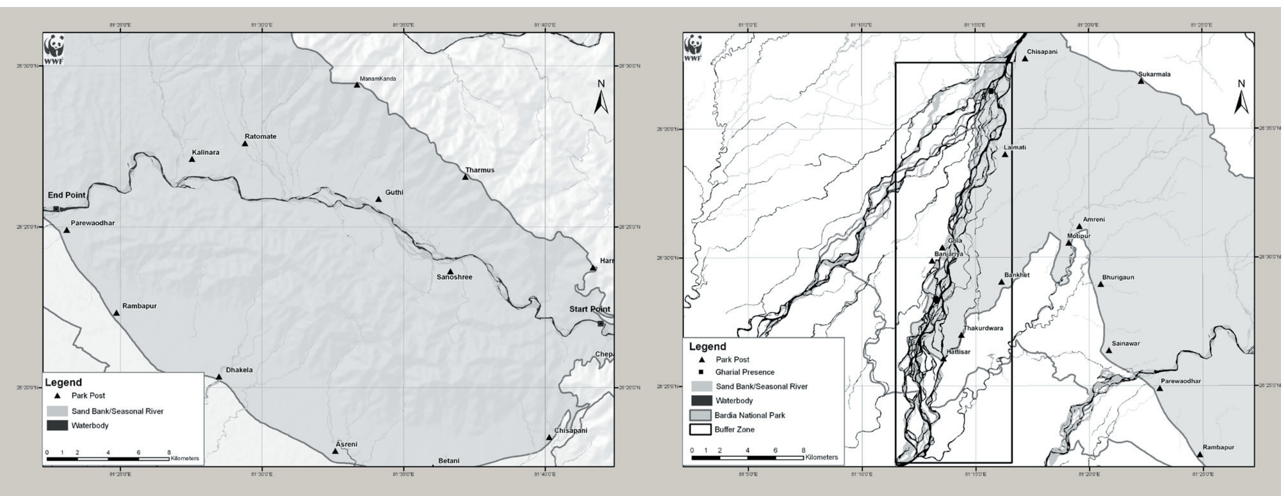

Figure 2: Karnali River (left) and Babai River (right).

Objective 1: To establish baseline data on status (population size, density, size classification, adult sex-ratio) and spatial distribution of the species.

Methods: Basking sites in Nepalese river systems are devoid of vegetation which could have otherwise hindered sighting of Gharial. Thus, with visibility bias being almost negligible, total counts of basking Gharial was adopted for estimating population size, with an assumption that all Gharial would come out to bask during the survey season (winter months, late February to early March). The major drawback of this method is that it does not take into account detection probabilities. However, to check the variation in the count and to ensure greater detectibility, sampling effort was increased to three times for each of the river segments surveyed. The river segments were identified on the basis of past studies (Khadka *et al*. 2008) and divided into segments based on the approximate distribution of river length and ease of field logistics.

Table 1. Survey data for 19 February 2011 (Day 1), 20 February 2011 (Day 2) and 21 February (Day 3) in CNP. Numbers in brackets indicate relative densities (ind./km) of the maximum sightings.

River	Segment	km	Day 1	Day 2	Day 3
Rapti	Itcharni-Kasara (1)	25.04	16	18	20
	Kasara-Rapti Narayani confluence (2)	20.27	10	12	9
	Reu River		0	3	0
	Buddhirapti (7)	7.38			
	Total	78.07	26	33 (0.42)	29
Narayani	Sikrauli-Amaltari- East (3)	25.38	16	23	19
	Sikrauli-Amaltari-West (4)	26.78	3	9	10
	Amaltari-Bagwan (5)	20.47	2	2	4
	Bagwan-Triveni (6)	22.04	11	14	8
	Total	94.67	32	48 (0.51)	41
Karnali	Chispani-Kothiaghat (1)	37.00	1	1	4 (0.11)
Babai	Chepang-Guthi (1)	21.5			
	Guthi-Parewaodar (2)	18.5			
	Total	40.0	14	17 (0.43)	9
Koshi	Chatara-Koshi Barrage (1)	39.00	0	0	0

Field personnel were divided into groups of 4 people (2 trained observers and two boatmen). Each team reached the starting point of each segments and started the survey around 15-30 minutes after sunrise (correlating with the time of maximum basking activity) and continued till the segment ended. Each segment was completed in approximately 2-3 hours. Therefore, each team started and completed in almost the same time period of the day. Observers were equipped with Nikor binoculars (10 x 50), Garmin GPS and standard data sheets. Two observers with binoculars scanned either side of the river banks looking for Gharials and recording data on every direct sightings while the two other people paddled the boat. Size-classes were determined by calibrating natural objects/features and by setting up measured reference markers (placing a 3 m stick) at basking sites. Total Gharial body length was measured from head to tip of the tail (Bustard and Singh 1977). Individuals <90 cm long were considered to be yearlings, 90-180 cm as juveniles, 181-300 cm as sub-adults, and >300 cm as adults (Nair 2010). Similarly, only adult animals were "sexed", with males being distinguished from females by the presence of a ghara.

Results: Population Estimate: Of the three consecutive surveys, the highest count was recorded on Day 2 in the Rapti, Narayani and Babai Rivers, while in Karnali it was Day 3 that was the highest; these maximum counts were considered for population estimation. Based upon the results of three different replicates, population size was estimated as 102 ± 6 (Koshi 0; Karnali 4; Babai 17; Narayani 48; Rapti 33; Table 1). No Gharial were recorded in the Koshi River, despite the release of 10 Gharials in 2010.

Density: The Gharial population density in all of the surveyed river systems of Nepal was low as compared to Chambal River (Table 1).

Size Distribution: Most (36%) animals sighted were in the sub-adult category, with adults and juveniles comprising similar proportions (29%) each. Surprisingly there were 5 yearlings (5%) also recorded (Table 2).

Table 2. Size distribution of Gharial sighted in Nepalese river systems.

River	>300 cm	181-300 cm	90-180 cm	<90 cm
Rapti	6	10	17	0
Narayani	16	17	10	5
Babai	7	8	2	0
Karnali	1	2	1	0
Nepal	30	37	30	5

Sex Ratio: Based on Gharial considered to be adults, the sex ratio was biased towards females in all rivers surveyed [Rapti 1.0 (N= 6), Narayani 0.88 (N= 16), Babai 0.71 (N= 7), Karnali 1.0 (N= 1), all 0.87 (N= 30); expressed as proportion of females].

Spatial Distribution: Gharial distribution was mapped using Arc GIS 9.3.Gharials were not uniformly distributed across the segments and also within the segments species showed concentration at few selected locations.

In the Narayani River, Segment 3 (Sikrauli to Amaltari East) had the highest concentration (23 animals), followed by Segment 6 (Bagwan to Tribeni) with 14 individuals. In both of these segments 2 Gharial hotspots were confirmed; Khoriyamuhan, where as many as 20 individuals were seen, and Velauji area at which11 individuals were recorded.

In the Rapti River, Gharials were more uniformly distributed compared to other river segments. Segment 1 (Itcharni-Kasara) had the highest number of gharials (20), and Dudhaura Charhara was identified as a Gharial hotspot with 12 individuals.

Similarly, in the Babai River Gharials were mostly localized in three locations - Chepang, Guthi, Kalinara and Parewaodar. Very few sightings of Gharial in the Karnali River were recorded from Helipad and Lalmati area.

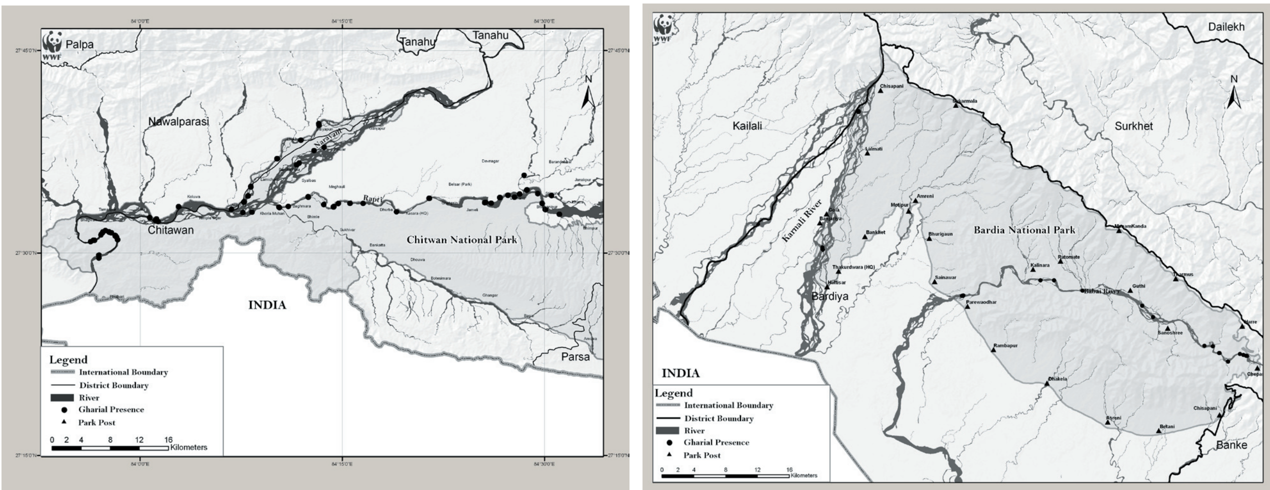

Figure 3. Spatial distribution of Gharial in Chitwan (left) and Bardia (right) National Parks.

Discussion: We found significant difference in Gharial sightings in the rivers across three replicates (ANOVA, F= 2.634, p<0.05) therefore indicating a single survey is not sufficient to provide reliable information on population status. During a countrywide survey of Gharial in 2008 the estimated population was 81 individuals (DNPWC 2008). Going back to the release data since the last count of 2008, DNPWC re-introduced 70 more Gharial in the Rapti, Koshi, Karnali and Babai Rivers but the population increase is only 21%. In the best case scenarios if all the released Gharial had survived since 2008 the population would have increased by 86%. Similarly, since 1991-2011, DNPWC released 761 Gharials in different river systems of Nepal. However, the surviving population is only 13.4% of the total released population. This clearly indicates that the re-stocking program in Nepal is not meeting the long-term species conservation goal in the wild and therefore warrants efforts to understand the problem in the wild and address them accordingly. Size-class distribution of Gharial in the wild in Nepal is the product of Gharial surviving from different released years. Adult males and females surviving in the Rapti, Narayani and Babai Rivers are the ones released prior to 1997. The presence of few yearlings also suggests that a nest or two might have gone undetected during collection, and producing hatchlings in the wild.

Objective 2: To assess the factors governing gharial presence and quantify threat covariates

Methods: To assess the factors governing Gharial presence, habitat variables (water flow, river stage, river width, presence/absence of sand bank and river confluence) was recorded every 500 m in the Rapti and Narayani Rivers. Similarly, food availability (prey weight) was quantified every 5 km by throwing hand-net 3 times in the river. Water samples were collected every 5 km along the entire Rapti and Narayani Rivers, and were tested for parameters viz: pH, EC, turbidity, TDS, BOD, COD, DO, nitrogen and phosphorous content. Water samples were tested at ENPHO (Environment and Public Health Organization) and WETC (Water Engineering Training Centre) laboratory.

Disturbance (fishing, sand mining, stone quarrying, human intensity, boat intensity, washing, bathing and cattle grazing) was recorded every 500 m. Similarly, Gharial presence-absence data was collected at every 500 m.

Table 3. Variables quantified for assessing habitat quality requirements.

	Variables	Measured	Equipment	Covariates
1	Stage height-river level (m)	every 500 m	Staff gauge	Change in river level
2	Channel width (m)	every 500 m	Range finder	Mean channel width
3	Presence of sand bank (+/-)	every 500 m	Soil texture tests	clay, loam, sand, gravel, rock
4	Height of sand bank (m)	every 500 m	Ocular estimation	
5	Water flow (m/s)	every 5 km	Floating method	
7	Fish (prey) weight (g)	every 5 km	Hand net, balance	
8	Presence of river confluence (+/-)	every 500 m	-	
9	Temperature	every 5 km	Thermometer	
10	pH	every 5 km	pH meter	
11	Turbidity (NTU)	every 5 km	Turbidity meter	
12	TDS	every 5 km	TDS meter	
13	Electrical conductivity (EC us/cm)	every 5 km	Conductivity meter	
14	Nitrate (mg/L)	every 5 km	UV-VIS Spectrophotometer	
15	Total Phosphorous (mg/L)	every 5 km	UV-VIS Spectrophotometer	
16	Dissolved oxygen (DO mg/L)	every 5 km	Iodometric Titration	
17	Biochemical oxygen demand (BOD)	every 5 km	5 days incubation	
18	Chemical oxygen demand (COD)	every 5 km	Open Reflux Method	

Factors governing Gharial presence: Stepwise regression analysis was carried out to compare the factors governing gharial presence. Of the different parameters entered (Sand bank, Sand bank height, River width, River level, Water flow, River confluence, Cumulative Disturbance Index and Prey weight) three factors that positively influenced the distribution are sand bank ($t= 3.7$, $p<0.01$) prey weight($t= 3.1$, $p<0.05$) and river confluence ($t= 3.1$, $p<0.05$).

Habitat occupancy: Program Presence version 2 (Hines 2006) was used to model the habitat occupancy of Gharials by fitting the detection/non-detection data (MacKenzie 2005) with the above mentioned parameters as covariates. The model with the lowest AIC was selected over the other models that explained the most variability. The model that incorporated sand bank, river confluence and cumulative disturbance was the best performing model to describe habitat occupancy by Gharials in Rapti and Narayani Rivers. Using the top model with lowest ΔAIC=419, and AIC weight (w) of 1, the Gharial habitat occupancy pattern in the Rapti and Narayani Rivers ranged from 0.052 (SE= 0.028) to 0.81 (SE= 0.035).

Table 4. Probability of occupancy (PSI) estimates generated with covariates with sand bank, river confluence and cumulative disturbance (each of the 40 segments was 5 km).

Segment	PSI	SE	95% Conf. Interval	Segment	PSI	SE	95% Conf. Interval
1	0.0956	0.028	0.052 - 0.166	19	0.2779	0.049	0.192 - 0.383
2	0.1008	0.026	0.059 - 0.165	20	0.4656	0.077	0.321 - 0.615
3	0.1062	0.028	0.061 - 0.176	21	0.4996	0.027	0.446 - 0.552
4	0.1752	0.034	0.117 - 0.252	22	0.2274	0.042	0.154 - 0.321
5	0.2998	0.029	0.245 - 0.360	23	0.2783	0.038	0.208 - 0.360
6	0.6097	0.027	0.555 - 0.661	24	0.5112	0.057	0.399 - 0.621
7	0.153	0.038	0.091 - 0.244	25	0.1567	0.029	0.106 - 0.223
8	0.7558	0.035	0.679 - 0.818	26	0.3122	0.026	0.262 - 0.366
9	0.3969	0.036	0.327 - 0.471	27	0.7244	0.032	0.657 - 0.782
10	0.5214	0.068	0.388 - 0.651	28	0.5697	0.037	0.495 - 0.640
11	0.4664	0.034	0.403 - 0.530	29	0.2225	0.035	0.160 - 0.300
12	0.47	0.031	0.403 - 0.537	30	0.5919	0.058	0.474 - 0.699
13	0.4261	0.035	0.366 - 0.488	31	0.5991	0.042	0.513 - 0.678
14	0.6339	0.039	0.561 - 0.701	32	0.5071	0.022	0.462 - 0.551
15	0.4011	0.039	0.327 - 0.479	33	0.7693	0.046	0.665 - 0.848
16	0.6872	0.039	0.604 - 0.759	34	0.8949	0.029	0.820 - 0.940
17	0.7531	0.031	0.686 - 0.809	35	0.6713	0.023	0.624 - 0.715
18	0.6131	0.03	0.552 - 0.670	36	0.4187	0.018	0.382 - 0.455

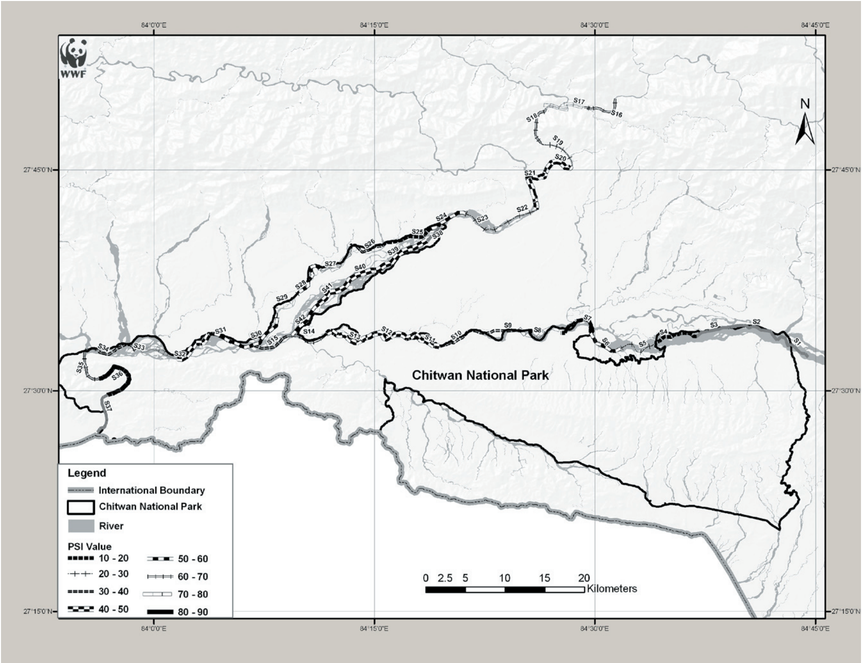

Figure 4. Gharial habitat occupancy in Chitwan NP based on PSI values generated through occupancy modeling.

Water Quality Test: Of the 40 water samples from 40 different stations in the Rapti and Narayani Rivers, only samples from 2 stations (nearby Brikuti Paper Mill area and Tuborg Beer Factory) were below the minimum standard prescribed for aquatic fauna. Although Bhrikuti Paper Mill and Tuborg Beer Factory claim to have Boiler Wet Subscriber Treatment Plants, the results indicated that the plants were non-functional during the research period. All parameters from the remaining 38 stations met the requirements (Table 5).

Table 5. Water quality results from 40 stations. Bhrikuti Paper Mill and Tuborg Beer Factory were below minimum standards.

	Location	Temp. (˚C)	pH	TDS (ppm)	Turb. (NTU)	EC (us/cm)	Nitrate (mg/L)	Phosph. (mg/L)	DO (mg/L)	BOD	COD
1	Pokhara Buspark	7	8.4	219	1.1	270	0.5	<0.1	9.6	0.4	6.5
2	Bhirkuti Paper Factory	22	7.4	628	205	788	3.5	0.4	3	240	2325
3	Shivnagar	17	8.4	8	1	250	0.8	<0.1	7.4	0.3	10
4	Pitauji Ghat	17	8.5	220	1.7	258	0.6	<0.1	8.8	0.3	13.5
5	Tuborg Beer Factory	17	7.4	1479	243.7	1761	8.9	53.7	0	525	2950
6	Sikrauli Ghat	19	8.5	223	1	255	0.8	<0.1	9	0.2	13.5
7	Kujauli	17	8.9	217	1.3	278	0.6	<0.1	9.5	1	8
8	Divyapuri	17	8.8	213	1.3	356	0.8	<0.1	12.7	0.4	6.5
9	Gohi tappu	17	8.3	211	2	385	<0.2	<0.1	9.5	0.9	13
10	Island Jungle Resort	19.5	8.5	201	2	262	0.57	0.02	7.1	0.5	3
11	Amaltari	20.5	8.8	197	2	258	0.45	0.01	8.2	1.7	7
12	Temple Tiger Ghat	19.5	8.7	203	3	267	0.69	<0.01	4.9	1.4	7
13	Nandapur	19.5	8.5	207	3	266	0.42	<0.01	5.8	1	3
14	Seri	16	8.5	212	2	270	0.57	<0.01	6.4	1.2	7
15	Tamaspur	18.1	8.5	208	3	267	0.5	<0.01	7.2	1.1	4
16	Bagwan	20	8.6	207	3	268	0.48	<0.01	8.5	0.76	3
17	Velauji	18	8.5	210	4	267	0.47	<0.01	7.6	1.1	6
18	Velauji	19.8	8.5	213	3	266	0.57	<0.01	7.2	1.3	4
19	Tribeni	19.5	8.4	214	2	267	0.69	<0.01	6.9	1.7	9
20	Lothar Machan	22	8.2	169	2	214	1.6	<0.01	6.2	0.42	1
21	Dubi Chowk	22	8.5	169	3	232	1.3	<0.01	7.1	1.2	4
22	Kumratha	22	8.6	181	3	226	1	<0.01	7.9	0.53	1

Table 5 cont'd. Water quality results from 40 stations. Bhrikuti paper mill and Tuborg beer factory were below minimum standards.

	Location	Temp. (˚C)	pH	TDS (ppm)	Turb. (NTU)	EC (us/cm)	Nitrate (mg/L)	Phosph. (mg/L)	DO (mg/L)	BOD	COD
23	Itcherni	21	8.5	176	4	211	0.2	<0.01	11.4	1	2
24	Patnaghat	21.2	8.5	188	3	230	0.3	<0.01	10.2	0.76	5
25	Badrani	21	8.2	316	3	398	3.1	<0.01	7.8	1.1	7
26	Charara Ghat	20.1	8.2	218	5	300	0.65	<0.01	8.9	1.3	7
27	Jarneli	21.5	9.9	236	4	292	0.23	<0.01	9.2	1.7	6
28	Kasara	20	9.8	204	5	282	0.36	<0.01	10.7	2.2	6
29	Kasara Ghat	22	8.2	244	3	297	0.31	<0.01	6.5	1.2	6
30	Dhurba	22	8.3	246	2	306	0.29	<0.01	7.5	1.4	6
31	Sukranagar	22	8.3	250	2	302	0.32	<0.01	7.4	1.3	9
32	Budhanagar	18	8.2	248	3	297	0.41	<0.01	6.5	1.4	7
33	Meghauli Ghat	17	8.1	243	3	287	0.56	<0.01	9.5	4.4	9
34	Laukhani	20.4	8.3	247	4	296	0.54	<0.01	9.7	2.06	18
35	Jalbire	19.7	8.3	169	2	230	0.76	<0.01	8.5	1.2	10
36	Near Seti Confluence	19	8.4	174	3	218	1	<0.01	7.9	2.2	7
37	Dasdhunga	19.8	8.4	174	2	216	0.68	<0.01	3.1	1.3	12
38	Poultry Farm Area	17	8.4	165	3	215	0.7	<0.01	3	1.5	10
39	Chitwan Diary	17.1	8.4	171	3	219	0.8	<0.01	8.7	1.6	7
40	Devghat	17	8.4	180	3	228	0.68	<0.01	7.9	1.3	5

<u>Threat Quantification</u>: Both the Rapti and Narayani Rivers suffer tremendous pressure from various disturbances (Table 6). Of the total river surveyed (Rapti, 68.5 km; Narayani 108.5 km), the available habitat ("no" to "low level" of disturbance) for Gharial was 25 km in the Rapti and 47.5 km in the Narayani. The fishing methods used in the Rapti and Narayani Rivers were assessed and quantified. Likewise, the entire river segment studied was mapped based on the disturbance intensity (cumulative disturbance per segment) i.e no disturbance to high disturbance zone (Fig. 5).

Table 6. Threat quantification in the Rapti and Narayani Rivers.

River	km	Fishing	Sand Mining	Stone Quarry	Boat Intensity	Washing	Bathing/ Swimming	Cattle Grazing
Rapti	68.5	1.85	0.219	0.190	0.70	1.07	3.59	4.25
Narayani	108.5	0.61	0.13	0.36	1.07	0.99	1.00	2.19

Table 7. Fishing frequency (per day) in the Rapti and Narayani Rivers.

River	Rapti	Narayani
Arrow fishing	31	0
Baiting	1	13
Electric current	9	0
Gill net	44	35
Hand net	42	18

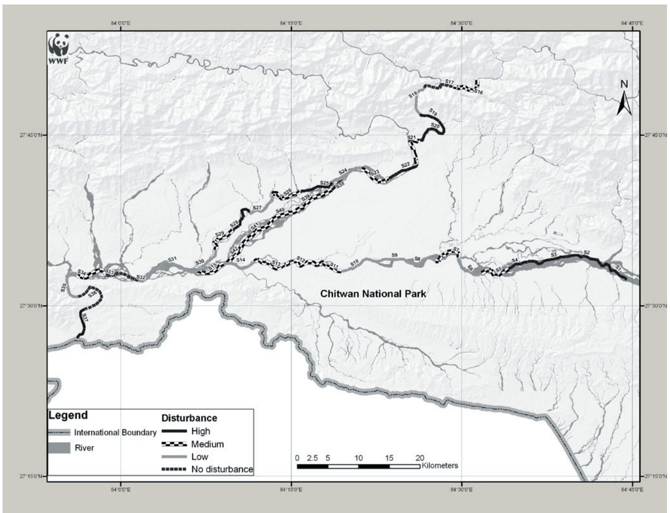

Figure 5. Disturbance intensity map for the Rapti and Narayani Rivers, 2011.

Discussion: Gharials were found to occupy river stretch with zero to very low level of disturbance, fine sand banks, especially deep pools with river confluence and greater prey availability. Water pollution level indicated only at the source point of Bhrikuti Paper Mill and Tuborg Beer Factory suggests that the water replenishing capacity is high in the Narayani River. The other fact that cannot be ruled out is the water load that could have diluted the effects in the river.

Objective 3: To upgrade the ex-situ facilities of Gharial Conservation Breeding Centre (GCBC), Kasara

As a part of upgrading *ex-situ* facilities in GCBC, two adult breeding pools have been constructed. These additional breeding pools have helped reduce overcrowding of the adults. Similarly, lab room has been renovated with a major objective of having fully equipped infrastructure within the breeding centre. It has been equipped with lab accessories such as laptop, camera, weighing machines, data loggers, pH meters, TDS meters, thermometers, etc. for record-keeping and management of captive Gharials. Likewise, a fish farm has been constructed adjacent to breeding pool with the purpose of raising finger size fish and feeding live fish to the Gharial in captivity. One of the predictions about captive-raised Gharial is that the hunting instinct/capability are diminished due to the dead fish (easy prey) provided thereby lowering the survival rates in the wild.

Objective 4: To build the capacity of the park rangers and wildlife technicians in captive management and scientific monitoring of Gharials.

Acknowledging the strong urgency of the skilled human resource to aid in conserving the critically endangered Gharials, WWF Nepal organized 4 days of training for 20 park rangers and wildlife technicians on various aspects of Gharial conservation, biology, captive management and monitoring techniques. The participants comprised of 10 rangers from Chitwan National Park and Shuklaphanta Wildlife Reserve and 10 wildlife technicians from National Trust for Nature Conservation. The major objective of the program was to develop manpower specifically for captive management research and regular monitoring of Gharial in Nepal. Since then, this trained manpower has been mobilized in various Gharial conservation and monitoring programs in Nepal.

As per the request of Government of Bhutan, WWF Nepal in co-ordination with DNPWC organized a 4-day short training course on "captive management of Gharials" to 5 staff of Gharial Conservation Farm, Gedo Forest Division, and Bhutan. Presently, Gharial Conservation Farm is performing better in terms of increasing the survival rates of Gharials and the government is planning for the restocking program in near future.

Objective 5: To aware the local communities and the publics on the plight of Gharials through conservation education and outreach programs

One of the major project emphases has always been on conservation education and outreach program. Gharial conservation education materials viz leaflets and brochures were prepared both in Nepali and English scripts (Fig. 6). The target groups reached out were local people around Gharial habitats, school students, eco-club members, hoteliers, nature guides and tourists. Brochure, "Gearing up for the Gharial" was also sent to various network offices around the world and is also available through WWF Nepal's resource centre. Electronic form of the brochure has been useful in reaching out to both national and international audiences.

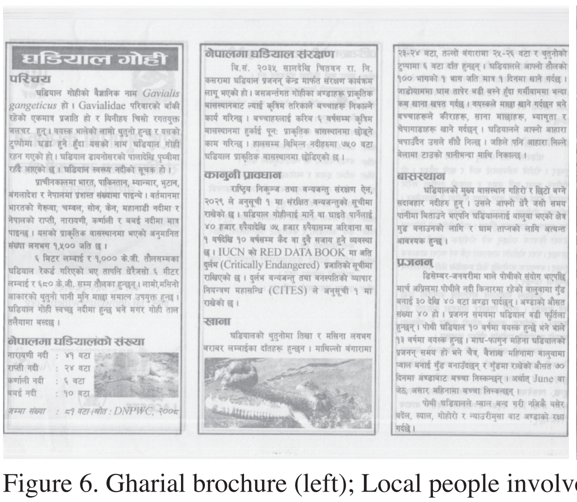


Figure 6. Gharial brochure (left); Local people involvement in Gharial Conservation Outreach Program (right).

Massive conservation outreach programs were successfully undertaken in 23 VDC (Village Development Committee) of Chitwan and Nawalparasi districts ensuring the participation of Bote, Majhi and Mushar communities (these are the river dependent communities). A total of 806 people from fishing community, 2000+ people from local community and 1200+people from buffer zone communities were directly sensitized in Gharial conservation. In the same way, Chitwan National Park being one of the most visited tourist center in Nepal, interactive workshop on gharial was organized for tourism entrepreneurs in Sauraha. A total of 26 nature guides and 49 hoteliers showed active participation and committed to raise their voices for Gharials.

Objective 6: To integrate favourable measures for Gharial conservation in the management of protected areas

Preparation of Gharial Conservation Action Plan (2012-2016)

Gharials still face a host of threats in the wild. Despite being 20 times more endangered than the tiger, the species conservation yet is not guided by any policy document in the country. Therefore it was realized that the country hold a strong guiding document with set vision, goal and strategies that identifies the highest priority conservation actions in their habitat for overall management of the species. Therefore, the task of Gharial Conservation Action Plan (GCAP) was also a top priority of this project and a team of experts are currently preparing the plan.

Preparations of the river management plan for critical Gharial habitats

Rivers have always been no man's property and protecting the rivers has always been a major challenge in Nepal. There are thousands of fishing communities living around rivers whose livelihood has been entirely dependent upon fishing. But, rather than traditional fishing, it is the commercial fishing, boating, sand mining, boulder extraction, dam construction and river diversion that are causing serious threat to Gharial habitat. Therefore, alike the need for species action plan at a national level, the local stakeholders strongly believed that unless, the two major river systems (Rapti and Narayani) in Chitwan National Park are managed properly and urgently, there is little hope for the survival of Gharials and other freshwater species in Nepal.

So through several round of discussions with the local stakeholders, consensus was reached that given the stake to the locals for managing rivers, they would support to managing river resources. This need has called for the "River Management Plan for Rapti and Narayani Rivers" and is also under development process. River management plan is expected to clearly spell out the stakeholders, resources to be managed and strategies for management.

Objective 7: To collaborate with GCA and reinforce gharial conservation in Nepal

GCA Collaboration

GCA's role to Nepal has been particularly important for providing scientific information and timely feedbacks on the project initiatives especially focused on scientific research and captive management. GCA's support to Nepalese officials in providing hands on training on captive management, scientific monitoring, capture and rescue techniques proved crucial in capacitating the park rangers, wildlife technicians and smart river rangers through similar kind of training organized in Nepal. Also, crocodile rescue techniques learnt in Crocodile Bank, Chennai has been implemented both in Rapti and Narayani Rivers and was possible to save the lives of three Gharials entangled in the gill nets in the Narayani River.

Reinforcing Gharial conservation in Nepal

- Formation of River Management and Gharial Conservation Sub-Committee: With increased awareness in gharial conservation, Bufferzone User Committee (BZMC), Chitwan, which is the legal body for managing buffer zone resources, has taken an important step to institutionalize the river management program. There are now altogether 5 River Management and Gharial Conservation Sub-committees in Rapti and Narayani Rivers.
- Mobilization of Smart River Rangers: At least 5-7 river-dependent communities (Bote, Majhi and Mushars) under each River Management and Gharial Conservation Sub-committees have been trained as "Smart River Rangers" to systematically monitor Gharial population and patrol the rivers. There are 5 teams of smart river rangers each assigned to patrol their respective river segments (ie two segments in Rapti and 3 in Narayani). Each of the team has 5 members comprising of two surveyors, two boatmen and one game scout. Game scout is officially appointed by Chitwan National Park to accompany the team in every month's patrol and monitoring operation. The team surveys their respective river segment 1-2 times a month and collect data on gharial status and illegal activities. The team also has the authority to warn the illegal fishermen and seize the fishing nets in the river. (Fig. 7). This team has been monitoring Gharial population in the Rapti and Narayani Rivers since October 2011. The team's effort in monthly patrol has been useful in keeping a track of Gharial population in each river segments. Similarly, it has been instrumental in minimizing and keeping a check on illegal activities in rivers, reducing the use of gill nets, reduction in reported cases of entangling of Gharials and timely rescue. This year 3 Gharials entangled in the nets were successfully rescued by smart river rangers and park staff. From October, 2011 to May, 2012 smart river rangers had 581 sightings of Gharial in 5 river segments.

Altogether 119 gill nets were seized and burnt by smart river rangers leading to decline in the usage of gill nets in the latter months. Likewise, 11 people using electro-fishing were punished. Similarly, there has also been decline with sand mining, stone quarrying and other illegal activities in the river.

Figure 7. Smart River Rangers Team patrolling the river.

- Livelihood support for river dependent communities: Altogether 10 community fish farms have been supported through the project in different parts of bufferzone area of Chitwan National Park. The objective of providing support to community fish farm is to lower the fishing pressure in the rivers by targeting fishing communities who compete for the same fish resources. The strategic locations for community fish farms were selected based on the intensity of fishing problem in the area. Of these 4 community fish farms are constructed in Amaltari area, 2 in Laukhani, 1 in Rajahar and 3 in Jagatpur. Likewise skilled development training such as tailoring, driving, cookery, handicraft making was provided to 100 river-dependent communities in Amaltari, Bagwan and Laukhani areas of Chitwan.
- Gharial Restocking program in CNP: With the initiation of smart river rangers program, rivers within CNP are considered better protected from disturbances; so gharial restocking program was rejuvenated. A total of 100 captive Gharials (19 males, 81 females) were released into different section of Rapti River between January and April 2012 (Fig. 8). These released individuals comprised of animals hatched in the period 1997-2006. All the Gharials were measured, sexed and marked by scute cutting for easier identification of the animals. Animals were loaded into a ventilated wooden box of size (20 x 30 x 180 cm) and transported to the enclosure near by GCBC. Enclosure made of *Narenga* spp. were good enough for fish to come and would allow Gharials to get acclimatized before finally breaking the enclosure and escaping into the natural habitat. At present there are 582 gharials in captivity at GCBC, and 861 captive-reared Gharials have been released as of April 2012 in different river systems of Nepal.

Figure 8. Gharial released in enclousure at Rapti River.

Figure 9. Gharial being rescued in the Narayani River.

Major Project Outcomes

- Gharial Conservation Action Plan developed
- River Management Plan for Rapti and Narayani Rivers developed
- *Ex-situ* conservation measures (2 Adult Breeding pool, lab, fish farm, visitor centre) upgraded in Kasara, Chitwan National Park
- Formation of River Management and Gharial Conservation Sub-Committee
- Capacity building and mobilization of river-dependent communities(Bote, Majhi, Mushar) as smart river rangers in patrolling rivers and monitoring gharial population
- Gharial rescue nets prepared and handed over to the Smart River Rangers team
- Alternative livelihood opportunities in the form of community fish farm and skill development training provided to river-dependent communities

Measurable Project Impact

- Increase in number of Gharial nests in the wild: In 2010, the year of project initiation, there were only 4 nests found in the Rapti and Narayani Rivers, which increased to 9 in 2011. This year it has increased to 11 and this increasing trend is the result of continuous monitoring of the population and strict protection of the river segments.
- Increased capacity of the captive breeding centre: Gharial breeding centre facilities are improved with the construction of two new breeding pools, lab, fish farm and enhanced visitor centre. 2012 was the year with the highest number of gharials in the history of GCBC; it supported 682 gharials of which 100 were released in Rapti River. Other indicators for increased capacity of the captive breeding centre is the "hatchling survival %" which shows an rising trend in the survival percentage of gharial after one year of age.
- Increased in Conservation Fee: Gharial Conservation Breeding centre started collecting entry fees since 2006; but till 2009 the revenue collected was very minimum (NRs 866,660). It almost doubled in the year 2010 reaching NRs 1,465,880 and has been increasing rapidly. Still one quarter of the year is left for this year's closing and more national and international tourist is expected.
- Successful rescue of entangled Gharials: This year 3 Gharials entangled in the nets were successfully captured and rescued with the help of the nets provided to the Smart River Rangers group. All 3 Gharials were finally released back into their natural habitat.
- Increased interest of Media in highlighting Gharial conservation: Local as well as national journalists are found to have increased interest in the species, they are documenting most of the project initiatives to bring about mass awareness both at local and national level.

Conclusions

Increase in nests number in the wild has brought optimistic hope in the future of this critically endangered Gharial. Similarly, the proposed telemetry study is expected to provide light into the fate of Gharial restocking program in Nepal. The ongoing species action plan is anticipated to get attention from all levels of stakeholders; from policy makers to decision makers and implementers in the field. River Management Plan shall provide guideline to usage of river resources, increased ownership taken by the river-dependent communities and control on usage and exploitation by commercial users. There has been growing awareness in local people about Gharial conservation and they are known to take pro-active measures. Smart river rangers program has been very successful and is able to minimize fishing incidences while keeping a check on other illegal activities in the river. Improvement in captive facility in the park has positive impact in the survival of gharials, better space management and increased number of tourists contributing to greater conservation fees for GCBC management. River-dependent communities have readily accepted the livelihood opportunities provided through the project. They have been supporting the conservation initiatives and are committed for long term conservation of critically endangered Gharial.

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A Newly Founded Non-profit Organisation Focused on Contributing Towards the Better Understanding and Conservation of Tomistoma (*Tomistoma schlegelii*)

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Abstract

The Tomistoma Fund is an established 501(c)3 public charity founded in May, 2011, to further promote funding and collaboration of efforts towards the research, conservation, and management of wild Tomistoma (*Tomistoma schlegelii*). As an endangered species in the IUCN Red List, there is an immediate need to further our scientific understanding of the species current geographic distribution, ecology, reproductive biology, behaviour, and diet in order to pursue future conservation and management efforts. The objective of this organization is to help facilitate Tomistoma research projects and initiatives in the aforementioned, but not limited to, fields of study. Equal in importance, our organization aims to promote local and international education and awareness for the species through literature and public presentations. As a newly founded organization, we do reverently request any possible guidance and supervision from organizations already developed towards Tomistoma research and conservation.

The Management of American Alligators in Louisiana, USA: A History, Review and Update

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Abstract

The American Alligator (*Alligator mississippiensis*) occurs in the southeastern United States and management programs exist in most states. Alligators are utilized in Louisiana and are managed as a renewable natural resource. Wild alligators are harvested in a controlled manner using strict guidelines and strong oversight at the state and federal level. Quotas are based on sound scientific survey methods to estimate regional population levels, and harvest levels set proportionally to estimated population levels in each locale. Alligator eggs are also harvested commercially on many wetlands, which avoids high natural mortality. The eggs are then hatched on licensed commercial alligator farms, and alligators raised for their valuable leather and meat. Mandatory release of juvenile alligators to properties from which eggs were harvested ensures future recruitment. This sustained use management regime benefits the landowner, alligator farmer, alligator trapper, and other industry personnel and promotes preservations of wetlands, due to the economic incentive of maintaining quality alligator habitat. Problem or nuisance alligators are relocated or harvested by licensed trappers to avoid human-alligator conflict. These programs have grown in magnitude since their inception and modification made with time as needed. This paper reviews the history, development, and current status of management of alligators in Louisiana.

Introduction

The Louisiana Department of Wildlife and Fisheries (hereafter Department or LDWF) manages the American Alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The Department's sustained use program is one of the world's most recognizable examples of a wildlife conservation success story. Louisiana's program has been used as a model for managing various crocodilian species throughout the world. Since the inception of the Department's program in 1972, over 836,000 wild alligators have been harvested, over 6.8 million alligator eggs have been collected, and over 4.1 million farm-raised alligators have been sold bringing in millions of dollars of revenue to landowners, trappers and farmers. Conservative estimates have valued these resources at over $US802,000,000, providing significant, direct economic benefit to Louisiana. The management and sustained use of this resource as a conservation tool has been documented in detail (Joanen *et al*. 1997).

This report provides a historical perspective; outlines the basis and philosophy of the Department's management program; reviews the federal Government's oversight and approval role for management of the alligator in the USA; discusses wild, farm, and nuisance alligator programs; briefly lists research activities; and reviews the revenue and briefly discusses expenditure information associated with the management program and the Louisiana Alligator Resource Fund. This paper serves to review the research and management that led to the development of a sustained use program, and how the management program in Louisiana has been adapted over the last 40 years. In particular, emphasis will be placed on changes made to the program since our last similar update at the 17th working meeting of the Crocodile Specialist Group (Elsey and Kinler 2004); some portions of that document are duplicated herein for introductory purposes.

Historical Perspective

Alligators have been used commercially for their valuable leather since the 1800s (Stevenson 1904). The history of trade in alligator hides has been outlined in detail (Joanen and McNease 1991). This harvest was generally unregulated throughout the 1900s, until a gradual population decline resulted in severely reduced harvests in the early 1950s. In 1962, the alligator season in Louisiana was closed, and research studies, focusing on basic life history factors were undertaken which led to development of a biologically sound management program. Studies included reproductive biology and nesting ecology, as well as telemetry, habitat preferences, and movement patterns of adult and juvenile alligators (Joanen 1969; Joanen and McNease 1970; 1972; McNease and Joanen 1974). Of tremendous importance was the establishment of a rigorous survey method to estimate and monitor population trends (McNease and Joanen 1978).

Aerial surveys of coastal alligator nests were initiated in 1970. Longitudinal north-south lines were flown along the entire coast of Louisiana. A total of 51 census lines were used, with 28 lines at 3.8˚ intervals in the three southwestern parishes, and 23 lines at 7.5˚ intervals in the remaining coastal parishes (McNease and Joanen 1978), for a sampling intensity of 0.76% of 1.3 million ha (3.2 million acres) of alligator habitat (excluding 0.4 million ha categorized as salt marsh).

From 1962 through August 1972, alligators were totally protected. During this time a myriad of state and federal laws regulating harvest distribution and allocation of take, methods of harvest and possession, transportation and export of live alligators, alligator skins and their products was enacted. Similarly, in 1970 the Louisiana legislature recognized that the alligator's value, age at sexual maturity, and vulnerability to hunting required unique consideration and passed legislation providing for a closely regulated experimental commercial harvest (Joanen and McNease 1981).

The goals of the Department's alligator program are to manage and conserve Louisiana's alligators as part of the state's wetland ecosystem, provide benefits to the species, its habitat and the other species of fish and wildlife associated with alligators. The basic philosophy was to develop a sustained use management program which, through regulated harvest, would provide long term benefits to the survival of the species, maintain its habitats, and provide significant economic benefits to the citizens of the state. Since Louisiana's coastal alligator habitats are primarily privately owned (approximately 81%), our sustained use management program provides direct economic benefit and incentive to private landowners, and alligator hunters who lease land, to protect the alligator and to protect, maintain, and enhance the alligator's wetland habitats. One of the most critical components of the management program was to develop the complex set of regulations which required individual applications for each property to be considered for tag allocation, landowner permission, proof of ownership and detailed review of habitat quality related to alligator abundance, all of which combined to equitably distribute the harvest in relation to population levels.

Initial Wild Harvests

In 1970, the Louisiana State Legislature (Act 550) gave the Department of Wildlife and Fisheries full authority to regulate the alligator season in Louisiana (Joanen and McNease 1991). After the initial surveys were conducted in 1970 and 1971, the LDWF developed a system of hunter applications, licenses, tags, etc., to initiate an experimental harvest of wild alligators, and distribute the take according to population levels. Based on field research and the telemetry studies, a harvest conducted in autumn (when nesting female alligators are in the remote interior marsh with new hatchlings at nest sites) would select the take for adult males, or immature alligators of either sex. During the period of total protection (1962-1971) alligator populations increased quickly and by 1972 the Department was ready to initiate its new sustained use management program.

In September 1972, the experimental alligator harvest was conducted in Cameron Parish, Louisiana. A total of 1350 alligators (80.3% males) were taken by 59 trappers in 13 days. A detailed analysis of the harvest was reported (Palmisano *et al*. 1973) and in 1973, Vermilion Parish was also included in the harvest, which was increased to 19 days. In that year, 2921 alligators were taken by 107 hunters. The program expanded with time, and Calcasieu Parish was also hunted in 1975. As nest surveys continued to show rising population trends, all coastal parishes were hunted starting in 1979; and by 1981 the harvest was expanded statewide. The wild harvest program has gradually increased over time to the point where approximately 30,000-35,000 wild alligators are harvested annually.

The quota for the total numbers of alligators to be allowed for harvest (how many CITES tags to be issued to landowners/trappers) is related to the population of alligator estimated to occur on each piece of property. The alligator nest count by aerial transect gives an estimate of the total population, based on the theory that a certain proportion of the entire population consists of nesting females. Population trends are monitored closely each year by the estimated coastal nest counts seen on aerial survey.

Transect lines (and therefore nest counts) are categorized into marsh types, based on the vegetative types present. Certain "indicator" species of plants, depending on their salinity tolerances occur in different marsh zones. The marsh types are fresh, intermediate, brackish, and saline with increasing salinity levels in each zone. Very little (if any) alligator nesting occurs in salt (saline) marsh.

Transect lines are also categorized by location of the parishes (counties) in Louisiana. Tag allotments are determined for each parish, by marsh type. For example, in 2003 in Cameron Parish, one tag was allocated for each 90 acres of fresh marsh, while 170 acres of brackish marsh were needed to qualify for one CITES tag. In the western portion of Vermilion Parish, high nesting rates were seen, and thus only 75 acres of intermediate or brackish marsh were needed to qualify for one CITES tag in 2003. Poorer habitat and lower nesting rates led to a quota of only one tag per 500 acres of brackish marsh in St. Bernard Parish. Each year the nesting surveys and prior year's harvest results are closely examined by biological staff to determine the tag allocations for each region. The very best quality habitat with the highest nesting density had a CITES tag allocated for only 55 acres of this quality habitat in 2011.

Oversight by the US Fish and Wildlife Service

Five years after Louisiana closed the alligator harvest season, the alligator was listed on the federal *Endangered Species Act* in 1967. At this time the alligator was considered an endangered species throughout its range. In March of 1974, Louisiana petitioned the Secretary of the Interior, requesting that populations of the alligator in Louisiana be removed from the list of threatened and endangered species in Cameron, Vermilion and Calcasieu Parishes. In subsequent years, similar petitions sought to reclassify the alligator, first in 9 additional coastal parishes in 1978 and then statewide in 1981. Each of these petitions was based on results of detailed scientific study and the demonstrated success of the early harvest programs. The development of these early management and wild alligator harvest programs have been described in detail previously, outlining the inventory methods, population surveys, establishment of harvest recommendations, and validation of hides taken (Palmisano *et al*. 1973; Joanen and McNease 1981, 1987a).

Export of alligator skins and products out of the United States is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty, which became effective in 1975, regulates the international trade in protected species; its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. The US Fish and Wildlife Service (USFWS) administers CITES requirements and controls for the USA. The species covered by CITES are listed on one of three Appendices, according to the degree of protection needed. Currently, the alligator is listed on Appendix II of CITES, because of its similarity of appearance to other crocodilians that are truly endangered or threatened.

In order to fulfill CITES requirements, the USFWS through a series of rulemakings, has developed a complex set of requirements with which the individual states, including Louisiana, must comply in order to be granted export approval for harvested alligators skins and products. The most critical component in these requirements is that the Department must certify, on an annual basis, that the harvest programs we administer will not be detrimental to the survival of the species. The "non-detriment" finding is predicated on our assessment of the current condition of the alligator population, including trends, population estimates or indices, data on total harvest, harvest distribution and habitat suitability evaluation. Additionally, the management program must provide for a rigorously controlled harvest with calculated harvest level objectives. All alligators and eggs harvested must be taken from specifically identified properties and all hides individually tagged (with approved, serially marked CITES export tags furnished by the USFWS). The USFWS requires strict accountability for each tag allocated to the harvester, requiring that all unused tags are returned at the close of the season.

Wild Alligator Management and Harvest Program Expansion

Beginning in 1970, when the Louisiana State Legislature gave the Department of Wildlife and Fisheries full authority to regulate the alligator season in Louisiana, the Department has annually inventoried alligator nest production throughout coastal Louisiana in order to assess the status of alligator populations. Results of annual alligator nest surveys are compiled to provide estimates of nest density (acres per nest) by parish and by habitat type (brackish, intermediate, or fresh). Private and publicly owned lands [state and federal refuges, and state owned WMAs (Wildlife Management Areas)] are compiled separately.

As the experimental harvests proved successful and the program gradually became larger, nesting surveys were intensified to ensure the harvest did not cause any detriment to the wild alligator population. Additional "B" transect lines were added in 1981 (McNease *et al*. 1994) at midpoints between the established lines to increase sampling intensity to a total of 106 lines. In 1999, another series of "C" lines were added (now 143 transect lines). The survey takes some 9 days and costs approximately $US60,000 annually.

With expansion of the program beyond the coastal marsh zone, other habitat types (cypress-tupelo swamp, northern lakes, dewatered marsh, transitional/deteriorating marsh) also have tag quotas. Further refinement of the analysis in recent years has even led to some parishes being subdivided into east and west zones; or even divided in thirds (east, middle and west).

To avoid large fluctuations in annual tag quotas due to weather-induced changes one year's nesting effort, the tag quota was changed to being based on the average of the most recent 5-year surveys in approximately 1992. Other factors such as size classes harvested in the prior year, sex ratios harvested, regional "nuisance" alligator complaints, etc., are all considered when carefully establishing harvest quotas for each area.

"Bonus" Tag Implementation

As the wild harvest program in Louisiana readily appeared to be sustainable, it was adapted again in 1999 to make use of the more plentiful alligators in the 4-5' size classes (122-183 cm). Starting in 1999, trappers were issued an additional quantity of "bonus" tags to be used on alligators less than 183 cm in length. The number of "bonus" tags issued was 10% of the trapper's regular quota. For example, a trapper whose normal CITES tag quota is 21 would also have been issued 2 bonus tags to be used on smaller alligators. The "regular" tags may be used on alligator of any size. A trapper who qualified for 43 regular tags would have been issued 4 "bonus" tags. Some 3200-4400 bonus tags have been issued annually since 1999; the average size was initially approximately 5'9" (175 cm) to 5'10" (178 cm). Fortunately these hides were generally much larger than the hides from the average farm-raised alligators in Louisiana which average 3.69-3.81' (112-117 cm) total length at that time. Thus the two markets had little (if any) overlap. The "bonus tag" program was well received by landowners and trappers initially, but when the economic recession led to lower demand and lower prices (especially for smaller hides) there was less interest in this component of the program. Over time, compliance also became an issue, with some trappers not abiding by the voluntary use of bonus tags on alligators less than 6' in length. Thus, the bonus tag program was suspended after the September 2008 season; and was not implemented in September 2009 or thereafter.

Processing Improvements and Hide Quality

The wild alligator harvest initially was limited to a few major land companies who hired local citizens to trap their quota, and trappers who harvested alligators from family owned land. Trappers would skin their own alligators, and sell the salted hides to buyers at local auctions. Alligator meat was sometimes used for home consumption. As the wild harvest expanded, centralized processing sheds were established by dealers. Trappers bring their lot of hides to the shed, or dealers transport alligator carcasses from rural collecting points to the processing shed in refrigerated trucks. The alligator meat has become a secondary source of revenue to benefit to landowner and dealer. Refinements in the alligator skinning procedure and care of the hide have been developed to try to minimize damages in transport, skinning, and storage, to maintain and improve the quality of the raw hide.

Recent changes by the Department have been enacted to attempt to spread the harvest out over several weeks of the thirty day season, as a limited number of experienced and skilled alligator skinners are available for this seasonal work. These include opening the wild season on a Wednesday (beginning in 1998) so some trappers will complete their tag allocation before the opening weekend, when more trappers can begin harvesting efforts unconstrained by work obligations. Additionally, two distinct harvest zones were established in 2007, with the East Zone season opening on the last Wednesday of August in each year, and the West Zone opening on the first Wednesday in September of each year. The wild harvest in Louisiana has developed into a multi-million dollar source of income for the state's landowners and trappers.

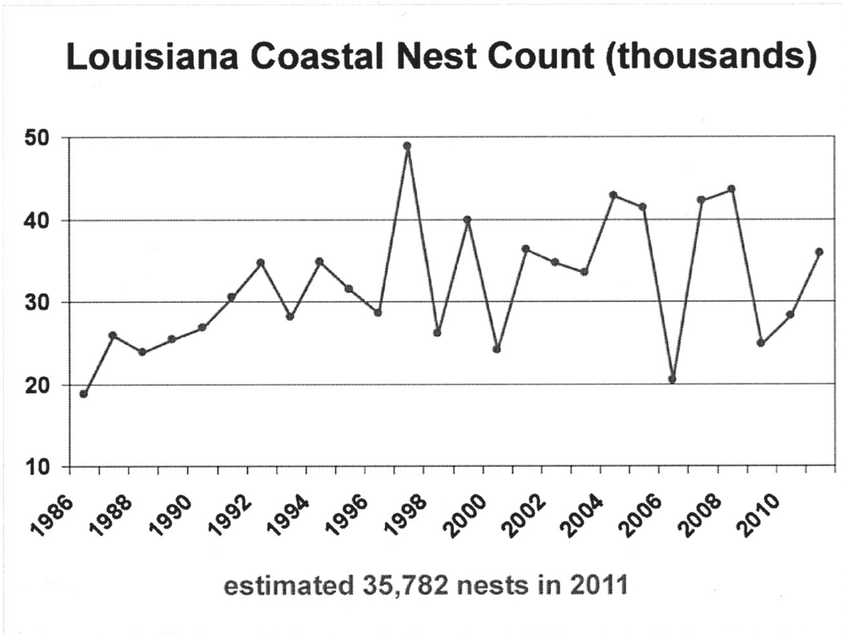
Survey Methods and Intensity; Establishment of Harvest Quotas

The vegetative type lines used to determine CITES tag quotas for wild alligators (and alligator egg quotas for ranching, see below) were initially delineated in 1968 (Chabreck *et al*. 1968). Numerous environmental factors such as salt water intrusion, wetlands erosion, etc. cause changes in marsh types over time. The vegetative type surveys were flown approximately every ten years (1978, 1988, 1997 and then 2001) to document the changes and adjust quotas accordingly. Recent efforts have been made to fly this survey more frequently (perhaps every five years) to closely monitor the critical problems of wetlands loss, saltwater intrusion, and marsh deterioration in coastal Louisiana.

Evaluating each trapper's family property or land owned by large private corporations and determining the quantity of various marsh types on the wetlands is very labor intensive. One piece of property may have divided interest ownership as the property was passed down from generation to generation. Property descriptions are obtained from tax assessor's offices in each parish to determine exact locations and boundaries for each piece of property. Maps of vegetative/marsh types and ownership are compared to calculate how many acres of each marsh type exist on each piece of property to be evaluated for CITES tag issuance. Until recently this has been done "by hand", an extremely labor intensive process considering the magnitude of the alligator habitat and number of commercial hunters in Louisiana.

A computer based GIS/ArcView system was initiated around the year 2000 to develop digital files of each landowner's property, with superimposed vegetative type delineations. This program now allows LDWF biologists to more easily incorporate the new marsh types or vegetative changes when new surveys are flown.

In June/July of each year, over 4000 km of transects are flown by helicopter, surveying 122,000 acres of wetland habitat. The sampling intensity covers approximately 3.4% of 2.3 million acres of private coastal wetlands, and 6.9% of some 622,000 acres of public coastal wetlands (up to 14.3% of some publicly owned wetlands are intensively surveyed). During the most recent summer survey, in 2011 we estimated that 35,782 alligator nests were present in the coastal marsh habitats, up from the 28,168 nests estimated in 2010. Although coastal habitats have significantly recovered from the devastating hurricanes in 2005 and 2008, nest production remained below average as drought conditions affected some coastal parishes during spring and summer 2010 and 2011.



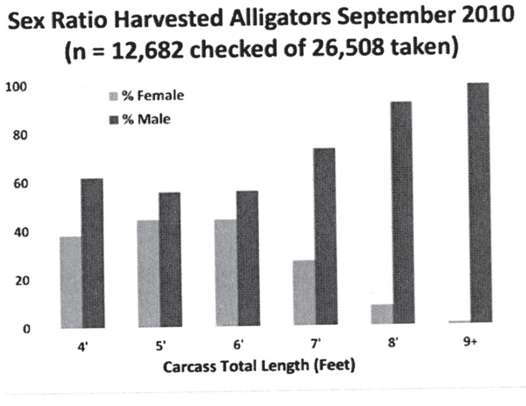
Nest density and alligator population estimates are combined with a detailed review of harvest parameters and a general assessment of environmental factors observed during each survey to determine final harvest level objectives. Over 50 individual alligator harvest quotas are developed annually in order to distribute the harvest in relation to alligator abundance in the various habitats across the state. As mentioned above, in the best habitat one alligator is harvested per 55 acres, while in the poorer habitats one alligator is harvested per 500 acres.

Alligator hunters annually submit a description of the property on which they have permission to hunt. The Department's biological staff assesses the habitat quantity and quality and determines the number of alligators that can be harvested by each hunter each year. This methodology ensures that alligators are harvested in proportion to their population levels and that the harvest will not negatively impact populations at any location, which is paramount for the "finding of no detriment" required by the USFWS for the harvest program. The currently approved quota system represents an allowable wild alligator harvest, which coupled with the state authorized wild alligator egg harvest program (see below) represents a level of population utilization currently unparalleled in the world of crocodilian management.

Under this sustained use alligator program, over 868,000 wild alligators have been harvested since 1972. The annual harvest takes place in September to specifically target the adult males and immature segments of the alligator population. Adult females, which typically inhabit interior marshes in September, would be more susceptible to harvest if the season was scheduled during the spring or summer. Careful evaluation of habitat parameters and ecological impacts can influence quotas established by Department biologists; for example severe drought led to lowered harvest quotas in 1996 and 2000. A combination of hurricane damage from the 2005 hurricanes and drought in 2006 led to accordingly decreased quotas in 2006. Minor adjustments such as delay in opening dates, temporary season closure, or season extensions have been made in emergency situations such as the catastrophic hurricanes in 2005 and 2008; to ensure the resource is used wisely.

In 2009 harvest was severely reduced due to worldwide economic recession which lowered price and demand for farm-raised and wild alligators. In 2010, demand and price for wild harvested alligators increased as the economic recovery began in Europe, Asia and in the United States). During the 2010 wild season, a total of 26,508 alligators were harvested by 2248 licensed alligator hunters. The sex ratio of over 12,000 of these alligators was 70.32% male. Alligators harvested averaged 7.5' in length, with an estimated value of $US5.3 million.

In 2011, as prices and demand for hides increased somewhat, trappers participated to a larger extent and 32,213 alligators were harvested by 2964 licensed trappers.



Each year the alligator program staff works closely with landowners and alligator hunters to provide assistance regarding alligator management on their respective properties. We have provided numerous habitat base maps to landowners for their use in participation of both the wild and alligator egg harvest programs. Harvest reports summarizing average lengths and size class frequency distribution of harvested alligators are available upon request.

Additional "Recreational" Harvest Opportunities

In recent years the LDWF has put tremendous effort into allowing additional "lottery" hunts for recreational alligator hunting on state-owned WMAs and public lakes, and allowed for some smaller properties to qualify for a single CITES tag. When hide prices are lower, some commercial trappers may be more inclined to host "sport" or "trophy" hunters as a means to gain additional revenue. The number of "sport" licenses sold (the majority are non-Louisiana residents) averaged 142 per year from 2005-2009, and increased to 197 in 2010 and increased again to 374 licenses issued in 2011.

Bar-coded CITES Tags

In order to streamline the alligator hide inspection process for validation prior to in-state tanning or export, the LDWF worked closely with the USFWS and manufacturers to develop, test, and implement the use of bar codes on CITES tags. This was started during 2008 and has proven to minimize the human errors associated with data entry errors (transposition of numbers or incorrect recording of numbers on paper documents) during mandatory hide inspections. Some technical difficulties were encountered as expected as this new technology was initiated, but over time various scanners have been tested and reliable models selected for use.

Farming/Ranching Program

Early alligator farms in Louisiana were generally small, family owned operations; and often run more as a hobby/curiosity than a commercial enterprise. Extensive studies done by Department biologists showed alligators could be efficiently cultured and grown in captivity (Joanen and McNease 1987b). To encourage a possible new industry, the initial few farmers were supplied hatchlings from eggs collected from state-owned lands, and incubated and hatched by Department personnel. A program was established wherein farmers would receive hatchlings from the LDWF for 10 years; by which time some of their first hatchlings received would be sexually mature and the farmer would then obtain eggs from his own captive breeders. As time passed, the captive breeding proved to be less economical than ranching of wild eggs, and the requirement to maintain captive breeders was eliminated.

Hatchling alligators fared well in heated "controlled environmental chambers" or sheds in captivity and could reach market size in 1-2 years. Soon the demand for hatchlings for this new industry could not be met from agency resources. The LDWF then developed guidelines and strict quotas (similar to how wild harvest quotas are determined) whereby potential ranchers might obtain eggs from suitable private wetlands, which historically have been shown to support substantial populations of alligators. Egg "ranching" (collection of alligator eggs from the wild) proved more economical and successful than captive breeding; and egg collections from privatively owned wetlands were first permitted, on a limited basis, in 1986.

Releases to the Wild - "Head Start" Alligators

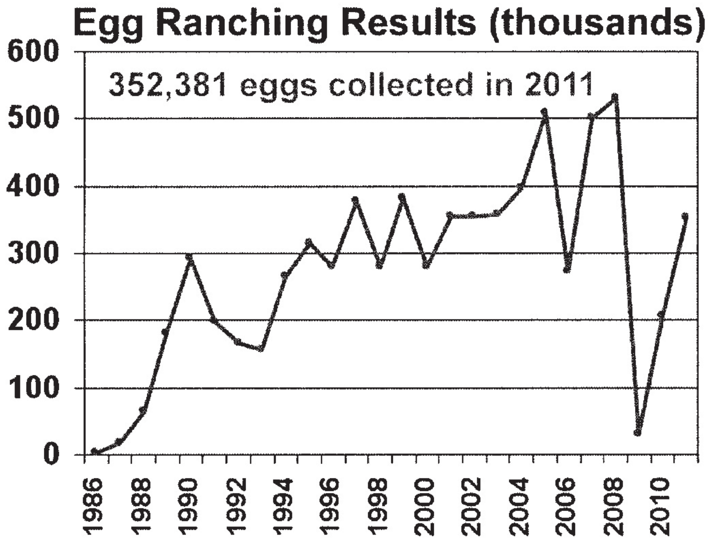
Louisiana's alligator ranching program increased dramatically between 1986 and 1990 and has been described in detail (Elsey *et al*. 2001). To ensure wild alligators were not depleted as a result of egg collections, and to ensure future recruitment of sub-adult alligators to the breeding population, the LDWF initially required a quantity of juvenile alligators equal to 17% of the eggs hatched by the rancher be returned to the wild within two years of hatching. In the first 3 years of the release program (1988-1990) returns were limited to fewer than 15,000 alligators. Sizes at release were generally small, and averaged 91-97 cm.

In 1991, a variable return rate was established based on the estimated 17% survival from hatching to 122 cm predicted for wild juvenile alligators. Using the relationship of survival between size classes as specified in Taylor and Neal (1984), we extrapolated return rates based on expected survival rates for alligators from 91.4 cm to 152.4 cm (3 to 5'). More alligators must be returned if the average total length is smaller, and fewer animals are required if the average length is larger. Alligators must be at least 91.4 cm and are usually less than 152.4 cm total length at release and must be free of disease or deformities to be acceptable for release (Elsey *et al*. 1998, 2001). Each alligator released is measured, sexed, tail-notched, tagged and this data is recorded by LDWF staff members prior to release to the same area where the farmers had originally harvested the eggs. The farmers must release the juveniles within 2 years of collecting and hatching the eggs.

Due to concern that the largest alligators on farms may be of poorer quality, the Department (at the request of a few landowners) briefly limited the maximum size at release to 54" (137 cm) rather than 60" (152 cm). Landowners were concerned these alligators (if caught in subsequent wild harvests) would reduce the grade of wild harvested alligator hides. These new size restrictions on released alligators were enacted for the 2007 and 2008 egg permits, but proved very burdensome for alligator farmers to have alligators of such a narrow range in length during the months of the year that releases to the wild are conducted. The Department allowed farmers to release 5% of their head-start alligators between the lengths of 55” to 60” to allow some flexibility, but this was felt to be an obstacle to the farmers and the “sharing” of one farmer’s unused over 54” allocation with other farmers was problematic for Department personnel to track, and this size limitation was discontinued after the second year.

Releases were initially made from 15 March to 30 September, if the weather was suitably warm. Due to conflicts with administration of the September harvest and field staff scheduling limitations, in 2003 the ending date for releases was changed to 25 August of each year (2001 egg collection permits; releases due in 2003). The tagging, marking, data collection and release procedure have been documented in detail (Elsey *et al*. 2001). In an average year some 35,000-40,000 juvenile alligators are marked and released to the wild; in the peak year of 2007, nearly 62,000 alligators were reintroduced as part of the “head start” program. Many of these survive well, grow into the adult size class, and are recovered and harvested as adults in the annual September harvest.

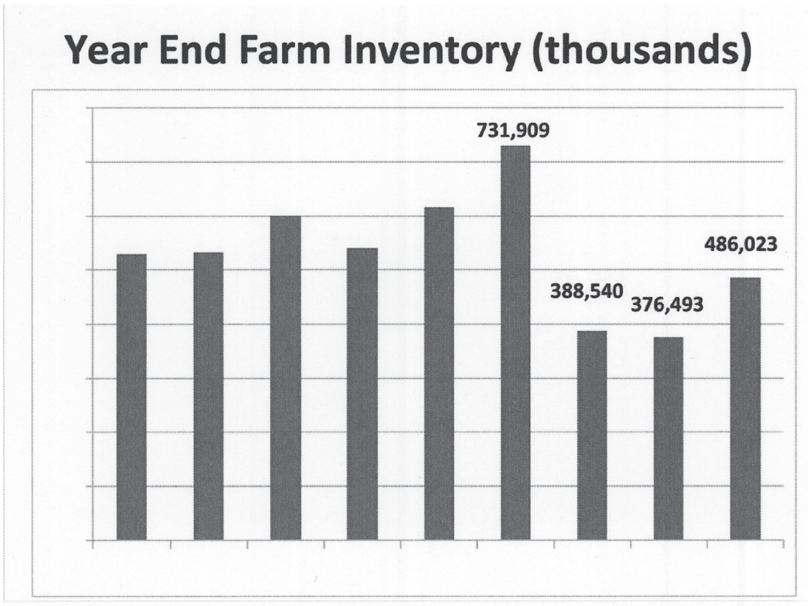
Enormous effort has been made by the LDWF to monitor the fate of the alligators released to the wild. We were very concerned that we document any failings or successes of the program, as it is costly to the ranchers to fulfill the “returns to the wild” obligation. However, it is an integral necessity of the program, considering the large number of eggs collected. In recent years, it has not been uncommon for up to 350,000-375,000 eggs to have been collected when weather conditions/ water levels led to good nesting efforts. In 2005, 2007, and 2008 over 500,000 eggs were collected in the ranching program; in recent years the Department has authorized collection of eggs on selected state-operated Wildlife Management Areas.



Our research and review of the ranching program documented that the released alligators are able to forage for food in the wild, grow well, have high survival rates, and successfully nest in the wild (Elsey *et al*. 2001). Thus, we decreased the return percentage to 14% of the eggs hatched, starting with the 2000 egg permit collection year (returns “due” in 2002; some done one year after collection in 2001). Similarly, the return percentage due was decreased again to 12% of eggs hatched starting with the 2007 year permits (returns due in 2009). Thus, our management program was adapted when available data warranted less demanding return requirements; although very close monitoring of the effects of this change will continue.

The number of alligator farms in Louisiana peaked during 1990-1992, when some 123-134 farms were licensed at any time (although not all were actively raising alligators). Some of this growth was undoubtedly a result of exceptionally high prices for wild alligator hides in the September harvests of 1988-1990, which ranged from approximately $48 per foot to $57 per foot (thus a single “average” sized alligator of 7 feet was worth some $400 for the hide alone).

Over time, many of the new, less experienced, and smaller farms were unable to compete with the more established farms, whose larger inventories and other factors led to their ability to maintain successful operations in years of more modest prices. The number of farmers/ranchers in Louisiana gradually dropped until around 1999, when it leveled off at around 60-65 farms; as of January 2012 there were 55 licensed farms. Again, many of these are small “hobbyists”, or others who simply maintain a farming license in order to ranch eggs, and transfer the eggs or new hatchlings to other farmers. However, the inventory on farms is far higher now (486,000 in December 2011) than when there were over 120 farms (318,000 in December 1991). The peak year-end farm inventory was 731,909 alligators in December 2008, just prior to the worldwide economic recession, which led to diminished egg collection efforts in 2009 and 2010.



With time, farmers experimented and have developed many techniques to improve efficiency and minimize costs of alligator production. Development of pelletized dry feeds with vitamin supplementation can avoid storage/freezer costs needed with frozen meat diets. Floating feed trays help minimize wastage. Sheds sometimes are constructed with multiple stacked levels to allow for housing of more alligators and more efficient use of heat. The use of heated refill water also encourages better feeding by maintaining constant warm temperature.

Beginning in 2007, we initiated a health surveillance program in conjunction with the Louisiana State University School of Veterinary Medicine (LSUSVM). Alligators are randomly sampled at alligator farms for a series of health profile tests (blood plasma and serum analyses, screening for West Nile Virus, Mycoplasma, etc.); in some cases full necropsies are performed to ensure alligators from cohorts to be released to the wild are healthy. Additionally, we have retained the services of veterinary staff at the LSUSVM for consultation, should an alligator farmer be concerned an alligator on his/her farm may be ill or developing any disease process.

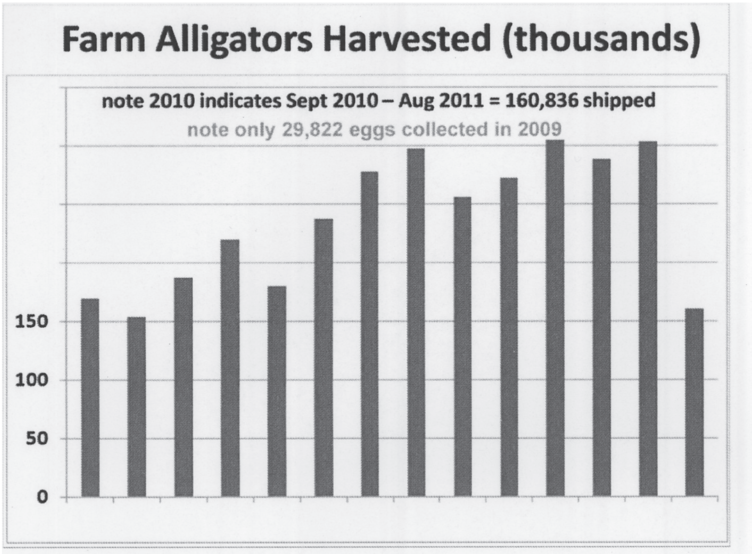
Hide Quality

As farm inventories increased, buyers and dealers were able to be more selective in choosing the highest grade/quality hides with which to prepare lots of hides to enter commercial trade. Increasingly stringent demands for near-perfect hides has been problematic for some farmers, as some portion of the hides produced will have damages due to scarring, bites, etc. Efforts are in place to find ways to continue to maintain excellent quality of skins produced on farms, such as use of deeper water (to avoid piling/scratching), hide boards (to limit stress and interaction with other alligators), vinyl liners (to avoid rough/abrasive surfaces), and filtered water (avoid possible infectious agents in standing water). Some farmers are experimenting with use of single pens in which to raise a single alligator by itself, to avoid any scars form fighting. Some farmers are also raising a portion of their alligators to larger sizes, although the majority are still sold as smaller alligators for the watchstrap industry.

Similar efforts are underway to maintain high quality wild harvested hides. Some problems (such as scars from fighting due to drought-imposed crowding) are unavoidable, but efforts have been directed to improving processing procedures (transport of carcasses in refrigerated trucks to avoid "slip" of scales, careful use of pressure washers to remove tissue remnants from hides, use of compressed air to assist in separation of the hide from the carcass and avoid knife/cuts to the hide, etc.).

Farm Production and Economic Crisis Factors

During the 2009 tag year (September 2009 through August 2010) a total of 301,017 farm alligators were harvested, averaging 28.62 cm belly width (4.58' in length). The total estimated value of these alligators was $US47.1 million. Although the data are still being compiled as skins are exported out of Louisiana, only an estimated 161,000 farm-raised alligators were harvested during the 2010 tag year (September 2010 through August 2011) reflecting the lowered egg collections in 2009 due to the economic crisis.



Beginning late winter and continuing into spring and summer of 2009, worldwide economic recession significantly impacted world trade in raw and tanned alligator skins and manufactured products. Price and demand for farm-raised alligator skins dropped precipitously during this period. The drop in price and demand coincided with the economic recession and with tanners implementing stricter quality standards. Throughout this period many farmers were unable to sell any skins; several farmers exported skins for crust tanning and later sale. Two of the largest alligator skin tanneries in the world made recommendations to the Department and alligator industry participants, urging actions which would act to reduce existing inventories of both live on-farm alligators and alligator skins. In June 2009 many farmers decided to forego egg collections in the summer of 2009 (only 29,822 eggs were collected) thereby reducing on-farm inventories of live alligators during 2009-2010. Coastal flooding associated with a tropical weather event during July 2010 limited egg collections to 205,261 eggs in 2010. Since early 2010, price and demand for both wild and farm-raised alligators has continued to rebound. Both the 2011 alligator egg harvest and the wild alligator harvest increased in 2011, with 352,381 eggs being collected.

Nuisance Alligator Program

The LDWF manages a statewide nuisance alligator control program. The nuisance program is designed to remove problem alligators in order to avoid potential human/alligator conflicts. Through the process of nuisance alligator hunter appointments and annual renewals the Department maintains a statewide network of qualified nuisance alligator hunters. Nuisance alligator complaints are phoned into various Department offices, where complaints are recorded and then forwarded to a nuisance alligator hunter in the vicinity of the complaint. Nuisance hunters respond promptly and catch and remove the alligator as deemed necessary. Hunters are allowed to harvest the nuisance alligator and to process the meat and skin of the alligator for commercial sale as reimbursement for their time required to investigate the nuisance complaint and handle the situation. This process provides for immediate response to problem alligators and for payment to the nuisance alligator hunter, thereby minimizing the program operating costs to the Department. Larger alligators are usually harvested, and smaller alligators may be relocated. Additionally, Department personnel are sometimes called to remove nuisance alligators as well.

During the winter and spring of 2009, the worldwide economic recession had a devastating impact on price and demand for alligator skins. Nuisance hunters were unable to sell large skins at profitable levels and had no sales for small (under 6' total length) alligator skins. In June 2009, the Department instituted a policy change which allows for nuisance alligator hunters to charge the complainant a fee of $US30 when they catch and remove a nuisance alligators under 6' (183 cm) in length. Preliminary records indicate this fee is rarely charged. Depending on market conditions in future years, further nuisance alligator policy changes may be necessary to ensure that appointed nuisance alligator hunters remain in the nuisance alligator program.

During 2010-11, a total of 63 nuisance alligator hunters were enrolled in the program; annually the nuisance hunters respond to an estimated 5,000 complaints and harvest some 1200-3000 alligators.

Lessons Learned

During the 40 years over which Louisiana's alligator programs have evolved, some segments have proven to be ineffective or problematic to administer, and were discontinued. For the wild harvest, in the early years "special skinning instructions" were used each year, to ensure no poaching would occur. In addition to the use of CITES tags, alligator carcasses had to be skinned in a certain fashion each year, and these instructions were not made known to trappers until the day before the season opened. This prevented prior harvest and storage of large alligators before the season opened. As centralized processing sheds for alligator carcasses were developed, the special skinning instructions proved burdensome. A legally taken, CITES tagged carcass might be improperly skinned by an inexperienced employee at a processing shed, and thus technically creates an "illegal" hide. Thus, the rule requiring special skinning instructions was discontinued. Starting in 1991 every wild or farm hide produced in Louisiana was inspected by a LDWF employee, to ensure the CITES tag is properly attached and all hides in the lot are listed on the shipping manifest.

As farm inventories became larger, and realizing that most farm hides are processed "on site" and in a controlled setting, beginning in late 2008 a policy was developed to allow for "partial" hide inspections of farm hides. Often farmers request thousands of CITES tags at a time, and these tags can be used in sequential order, which aids record keeping. In contrast, wild harvested hides can be brought to a processing shed and lots of hides are obtained from numerous trappers with CITES tags that are not in sequential order, thus record keeping is more challenging. If a farmer requests a "partial" hide inspection, some 10% of the hides are inspected (selected at random by LDWF personnel) and the farmer must sign off documenting that they requested a partial hide inspection, although a full inspection of every hide would be conducted if requested. Every wild hide must be inspected in full before a shipping label for export is issued. The use of bar coded CITES tags has helped eliminate record keeping problems due to human error.

An experimental spring/summer harvest at Marsh Island clearly showed that high numbers of adult females are harvested at this time; providing further data to reinforce the decision to have the adult alligator harvest in autumn, to select for adult males or immature alligators of either sex. It also clearly showed that conservative quotas must be set to avoid overharvest; this was discussed in detail by Elsey and Kinler (2004).

The development of the egg ranching program led to most farmers discontinuing captive breeding efforts, which have been less successful (Elsey *et al*. 1994) and less cost efficient. Captive breeding is still underway at some farms, one advantage being that the mandatory "12% returns to the wild" are not required for egg/hatchlings produced by captive breeders.

The wild ranching program also initially allowed for the collection of hatchlings, if ranchers preferred this option (to avoid construction and maintenance of egg incubators). A much higher percentage "return rate" was due (30% at 123 cm). Problems developed with the temptation for farmers to catch "hatchlings" that were older/larger than specified, and this program was discontinued.

Another problematic area which developed gradually as farmers tried to minimize costs was that less effort may be given to maintaining strict hygiene and husbandry. Obviously costs increase (heating water, labor, feed losses) the more often the alligator sheds are cleaned. We strongly encourage our farmers/ ranchers to maintain aggressive husbandry efforts. Most have learned that costs saved with lack of attention to husbandry might be offset by lower quality hides being produced, which are less valuable. Occasional "disease" outbreaks are often rectified by resuming stricter hygiene/husbandry practices. Similar problems occur in other species of intensively cultured livestock such as pigs, poultry, etc.

Best Management Practices

In 2011, the Department of Wildlife and Fisheries and the LSU School of Veterinary Medicine in conjunction with the Louisiana Alligator Farmers and Ranchers Association developed a document entitled "Best Management Practices for Louisiana Alligator Farming". The document details recommended practices to ensure animal welfare of captive reared alligators in Louisiana, including egg collection, hatching, rearing, release to the wild and euthanasia. This document will be updated as new information regarding any pertinent topic to alligator faming becomes available. The intent of this document is to ensure that licensed alligator farms and ranches are employing humane methods of working with alligators. Additionally the LDWF worked closely with Dr. Nevarez at LSU's School of Veterinary Medicine to investigate methods of euthanasia on commercial farms, and determine the most humane practice to recommend to the alligator farming industry. Results are currently being analyzed.

Future

The current level of harvest in Louisiana is clearly sustainable, as nesting counts are stable in southwest Louisiana and still gradually increasing in southeast Louisiana. Despite the harvest of wild adults and eggs in the ranching program, populations remain sufficiently healthy as to require a "nuisance" alligator program. Louisiana's alligator management programs employ many citizens and are a multi-million dollar industry (up to $US60 million in strong years) of tremendous benefit to the state.

Habitat Concerns

One threat or potential limiting factor to Louisiana's alligator population is habitat loss. Because the vast majority of Louisiana's alligators are in the coastal parishes, saltwater intrusion and wetlands/marsh deterioration from numerous causes are very real threats. The additional impacts of recent hurricanes will likely result in long term reduction of alligator habitat quality in coastal Louisiana. Some 20,000 acres (31 square miles) of coastal marshes are lost annually.

Vast resources by numerous state and federal agencies have been expended to attempt to limit these losses. Projects to restore/enhance marshes include construction of earthen terraces (to reduce wave action and turbidity), "breakwaters" and protection levees along coastlines, and freshwater diversions. Alligators benefit directly from these efforts to maintain/ enhance wetlands. The freshwater diversion projects (Davis Pond and Caernarvon) shift water from the Mississippi River in hopes of re-establishing more favorable salinity conditions for numerous fish and wildlife species. Some preliminary data suggests alligator nesting has improved in the areas enhanced by lower marsh salinity levels. It is critical that habitat changes are monitored, mapped and incorporated periodically into the alligator program. This will ensure that our harvest programs are adjusted accordingly for corresponding alligator population and habitat changes.

Hurricane Impacts

Coastal Louisiana was impacted by devastating hurricanes in 2005 (Hurricanes Katrina and Rita) and 2008 (Hurricanes Gustav and Ike). In both of these years, storm surges inundated coastal marshes with high salinity waters across virtually the entire coast of Louisiana; which is prime alligator habitat. Some direct alligator mortality was observed; but overall long-term impact of these storms on alligator habitat remains to be seen. Direct physical damage to wetlands through scour, scrapes, erosion, and rolling has been noted, and high salinities were accentuated by lower than usual winter rainfall after the storms, which might have tempered the deleterious salinities. Effects of these storms on the subsequent wild alligator harvest were significant in 2006; but harvest numbers in 2007 and 2008 returned to pre-storm levels.

Results of the 2006 coastal nest survey indicated significant habitat damages in southwest Louisiana and extreme southeast Louisiana resulting from Hurricanes Rita and Katrina respectively. Nest production in 2006 was the lowest on record since 1986. During the fall and winter of 2006-2007 marsh water levels returned to near normal and the habitat recovered significantly. In 2007, coastal alligator nest production increased dramatically as wetland habitats and alligator populations recovered. Alligator farmers collected near record numbers of wild alligator eggs in 2007. In 2008, nest production was excellent and farmers collected a record of 530,579 wild alligator eggs. Hurricanes in the fall of 2008 and lower than normal spring water levels in 2009 resulted in reduced nest production in 2009 as compared to 2008. Nest production recovered gradually in 2010, however drought conditions continued to plague southwest Louisiana during 2011; southeast Louisiana had good alligator nesting in 2011.

Education/Outreach

In order to better meet the needs of the alligator industry, the Department sponsors meetings for all segments of the industry (farmers, hunters, processors, tannery personnel, and landowners) which gives the industry participants an opportunity to prioritize and discuss the current issues facing the state's alligator industry. The Department also created specific e-mail (LAalligatorprogram@wlf.la.gov) and website (http://www.wlf.louisiana.gov/wildlife/alligator-program) addresses for the alligator program to provide additional and easier methods for alligator industry participants and the general public to ask questions and acquire information. Alligator program staff continues to compile and update contact information, including e-mail addresses, which are used to promptly notify participants of available and arising program information. In addition to the on-site visits, the staff communicates with farmers on a regular basis to schedule releases, hide inspections, live animal inspections, coordinate farm transfers, alligator egg collection permits, and to issue and follow up on CITES harvest tags.

The Department contracts with the LSU School of Veterinary Medicine to provide various services to the alligator industry. On numerous occasions the staff arranged for transportation of sick or problem alligators and sample skins from farms to the LSU Vet School for necropsy or skin evaluation. One of these contracts provides for the availability of a veterinarian to respond to farm related problems. Farmers know they can contact the program staff or Dr. Nevarez and get a rapid response to their problem. We also arranged collection and delivery of alligator research specimens to numerous graduate students and university faculty.

Despite setbacks from Hurricanes Rita and Ike, numerous wildlife groups, including university and graduate students, are hosted annually at LDWF's Rockefeller Wildlife Refuge in Grand Chenier, Louisiana, for educational purposes; as are professional representatives from domestic and international organizations. Presentations are made at various civic organizations and captive alligators are often loaned out for educational purposes.

Research Activities

The Louisiana Department of Wildlife and Fisheries conducts numerous research studies annually, covering a wide range of broad categories including field studies on nesting ecology, reproductive endocrinology, captive rearing and husbandry studies, evaluation of our management programs, and we often provide research specimens or samples to university personnel. The university staff members often have expertise (molecular biology, etc.) beyond what we could accomplish in a rural remote field setting, and their detailed lab studies often support research endeavors and lead to advanced degrees by post-graduate students. Research studies would be a topic for an entire separate report than the scope of this document.

Revenue and Expenditure Information

In recognizing that the Louisiana alligator industry is a vital aspect of Louisiana's economy and recognizing the many, varied national and international impediments to industry development, and the need to develop and maintain a total alligator conservation program, the Louisiana legislature established the Louisiana Alligator Resource Fund in 1991 (R.S. 56:279). This Act established a dedicated source of revenue intended to help defray the costs of the alligator program within the Coastal and Nongame Resources Division of the Department. The specific goals of the legislation are:

1. To provide salaries and financial support including associated indirect costs for the following positions, to provide a minimum of two full-time technical positions (biologists) and 8 nontechnical positions such as computer operators, secretaries, and wildlife specialists existing within the Coastal and Nongame Resources Division of the Louisiana Department of Wildlife and Fisheries.
2. To assist with funding for law enforcement activities associated with the alligator farm industry when surplus funds are available and recommended by the Louisiana Alligator Advisory Council.
3. To assist with funding marketing programs recommended by the Louisiana Alligator Advisory Council when surplus funds are available.
4. To actively fund research on all aspects involved with alligator conservation and to develop the techniques needed to enhance the commercial alligator industry.
5. To assist in funding management of the alligator population through proper management, harvest and farm facility management.

This legislation provides all the enabling language required to establish the Louisiana Alligator Resource Fund including sources of income, investing of the fund, and expenditures from the fund. Further R.S. 56: 253 establishes the alligator hide tag fee and the alligator shipping label fee, specifies the details of collection of these fees, and establishes that these fees shall be no more than $4.00 per hide or live alligator. R.S.56:256, provides for the collection of a $0.25 severance tax on each alligator hide taken within the state. R.S. 56:279 C (1) provides that all revenues received by the state from tag fees, alligator shipping label fees, and from the severance tax on alligator skins shall be credited to the Louisiana Alligator Resource Fund. The alligator industry should be applauded for supporting these legislative endeavors to create a self-generated source of revenue to develop and maintain the state's alligator management program.

Currently the alligator program staff in Louisiana consists of five full time biologists (and one biologist who is assigned to do alligator work as half of his duties), three wildlife technicians, one full time and one half-time administrative coordinators, and one data manager.

Summary

Louisiana's alligator management programs have clearly illustrated that controlled sustained use of the species is feasible. The wild harvest has been in place for nearly 40 years (since 1972), and the egg ranching program for 25 years (since 1986) and may appear to operate unchanged every year. However, constant adaptations are made to try to improve both programs. The annual surveys lead to review of harvest quotas and possible changes for each parish as marsh types change and nesting efforts are affected. Constant requests by user groups (farmers, egg ranchers, trappers, landowners, buyers, dealers and other industry personnel) are received and considered as the LDWF tries to safely manage the resource to the benefit of many user groups with varied interests.

Louisiana's alligator industry is unique. It has recognized the necessity of establishing a self-generated revenue source to provide the necessary regulatory and management efforts to effectively manage the alligator resource. The Department will continue to protect the alligator resource while striving to ensure long term, sustainable harvest programs.

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Crocodile Management and Research in the Northern Territory of Australia, 2008-2011

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Abstract

The wild populations of Saltwater Crocodiles (*Crocodylus porosus*) and the endemic Australian Freshwater Crocodiles (*C. johnstoni*) in the Northern Territory of Australia (NT) are managed by the Northern Territory Government, through the Department of National Resources, Environment, the Arts and Sport (NRETAS). The only exception is Kakadu National Park (KNP), where crocodiles are managed by the Commonwealth Government through Parks Australia. The primary aims of management are: (1) conservation of crocodiles through sustainable use where applicable (outside KNP); (2) monitoring of the population status and/or the impact of harvest; and, (3) control of problem crocodiles to promote public safety. The effective management of wild and captive crocodiles relies on evidence-based decisions, ideally derived from scientific research. The NT has a long history of pursuing crocodile research, and there remain many different people and organisations in the NT involved in research today. Some of the research programs currently being undertaken in the NT are summarized.

Management

The wild populations of Saltwater Crocodile (*Crocodylus porosus*) and the endemic Australian Freshwater Crocodile (*C. johnstoni*) in the Northern Territory of Australia (NT) are managed by the Northern Territory Government, through the Department of National Resources, Environment, the Arts and Sport (NRETAS). The only exception is Kakadu National Park (KNP), in which crocodiles are managed by the Australian Government through Parks Australia. The primary aims of management are: conservation of crocodiles through sustainable use where applicable (outside KNP); monitoring of population status and/or the impact of harvest; and, control of problem crocodiles to promote public safety. The management consists of the following components that collectively work as a mechanism to achieve the management goals.

Management Programs

Since 1987, the management of crocodiles in the Northern Territory has been governed by formal management programs, now with a 5-year life span, approved at the Territory level by the Administrator of the Northern Territory, and at the Commonwealth level by the Minister responsible for wildlife and the environment. The two programs currently in force are the: Management Program for the Saltwater Crocodile in the Northern Territory of Australia, 2009-2014 (Leach *et al*. 2009) and Management Program for the Freshwater Crocodile (*Crocodylus johnstoni*) in the Northern Territory of Australia, 2010-2015 (Delaney *et al*. 2010). Both programs are administered by NRETAS.

Both Saltwater and Freshwater Crocodiles are protected species under the *Territory Parks and Wildlife Conservation Act*, and at the Commonwealth level, under the Australian *Environment Protection and Biodiversity Conservation Act* which is Australia's enacting legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). *Crocodylus johnstoni* and the Australian population of *C. porosus* are both on Appendix II of CITES, which allows commercial use of wild populations subject to the demonstration of non-detriment and other conditions of Article IV of CITES (Regulation of Trade in Specimens of Species included in Appendix II).

Saltwater Crocodiles are and always have been serious predators (Caldicott *et al*. 2005) and for people to co-exist with abundant crocodile populations presents a number of challenges to the Territory community. On the other hand, crocodiles also provide significant opportunities through consumptive (skins and meat) and non-consumptive (tourism) uses. They are a valuable resource to both Indigenous and non-Indigenous people in northern Australia (Webb and Manolis 1993; Leach *et al*. 2009).

Historically, uncontrolled trade in Saltwater Crocodile skins between 1945 and 1971 stimulated intensive hunting that depleted the wild populations to the point of near extinction (Webb *et al*. 1984). It was unclear whether the remaining crocodile population had the capacity to recover when full protection of the species was introduced in 1971. In contrast, *C. johnstoni* were only hunted intensively for some 5 years, from 1959 to 1964 before protection (Webb *et al*. 1987). The skin of *C. johnstoni* had limited commercial value relative to *C. porosus*, and entered the market when the availability of the latter declined. Because *C. johnstoni* were considered innocuous relative to *C. porosus*, were endemic to Australia, and their hunting in large numbers within freshwater rivers and billabongs was unpopular with cattle station owners and the public, they were protected earlier, in 1964.

The recovery of the *C. johnstoni* population in the NT since 1964 went largely unnoticed by the general public. The species does not have a high profile as a predator on humans (Webb and Manolis 1989), although they occasionally bite swimmers (Hines and Skroblin 2010; Somaweera 2011; Lindner 2004). Furthermore, they tend to occupy upstream freshwater habitats away from populated areas (Webb *et al*. 1987). Since the late 1990s, their population status has changed greatly due to the arrival of cane toads (*Rhinella marina*, formerly *Bufo marinus*), which is discussed below.

In contrast, the recovery of the *C. porosus* population in the NT since protection (1971) quickly became the focus of public attention. The recovery of depleted populations was originally fostered on the basis of re-establishing them as an integral part of the NT wetland ecosystems. By 1979/80, the population had increased from an estimated 3000-5000 mostly small juveniles, to around 30,000 mostly larger animals (Webb *et al*. 1984). When a series of fatal and non-fatal attacks occurred within 12 months, and some crocodiles started attacking fishing boats, public concern about the population recovery increased. The negative view associated with increasing human-crocodile conflict threatened the conservation program, which was broadly aimed at rebuilding the wild population back to carrying capacity. Some people opposed any further expansion of crocodile numbers and calls for widespread culling became commonplace.

In the early 1980s the NT Government implemented an "incentive-driven conservation" strategy (Hutton and Leader-Williams 2003), through which the potential economic benefits of having large populations of crocodiles was actively promoted. Positive incentives were created through commercial activity (tourism, crocodile farming and ranching) and negative incentives countered by an active 'Problem Crocodile' control program. Ranching of eggs (the commercial collection of eggs from the wild for incubation and raising in captivity) was introduced as the safest strategy for sustainable use to reward landowners for tolerating crocodiles. The egg stage is an abundant and naturally vulnerable part of the life cycle and more importantly, it had the potential to make *C. porosus* nesting habitats on private lands a commercial asset, worth protecting, as had occurred with American Alligators (Alligator mississippiensis) in Louisiana, USA (Joanen and McNease 1987).

At that time, *C. porosus* was on Appendix I of CITES and no wild-caught animals (even if taken as eggs) could be traded internationally. In 1985 Australia was successful in having its *C. porosus* population transferred from Appendix I to Appendix II of CITES, specifically for ranching, so that farms could export the skins produced from the harvested eggs they purchased from landowners. In 1987, the first NT crocodile management program was approved by the Australian Government and skins derived from the ranching program began to be exported. In 1994, Australia obtained an unrestricted Appendix-II listing so that landowners with crocodiles, but no crocodile nesting habitat, could also receive commercial benefits from crocodiles through a wild harvest (Leach *et al*. 2009).

The NT Government initially fostered and assisted the establishment of the crocodile farming industry. This role is now largely free of Government, and over the last decade the industry has invested significantly in infrastructure to increase its capacity commensurate with the increasing availability of eggs. Competition for eggs has increased prices for landowners, including Aboriginal people in remote areas where conventional opportunities for economic development are limited. Skin exports have been rising continually over the last decade.

Saltwater Crocodile populations have recovered in the NT (Webb *et al*. 2000; Fukuda *et al*. 2011). They are abundant in most coastal wetlands, and they are no longer a threatened species. They continue to be viewed as a valuable commercial resource, generating wealth and employment in the community, which provides on-going incentives for their conservation. The continuation of a viable crocodile farming industry is recognized as the key economic driver for the Saltwater Crocodile Management Program. The incentive driven conservation approach explicitly encourages management practices that favour the Saltwater Crocodile and protects wetland habitats outside the boundaries of parks and reserves.

The Saltwater Crocodile Management Program addresses the balance that is required between conservation goals, sustainable harvest, a growing industry, and the maintenance of public safety. It focuses on mechanisms to improve public awareness and safety, on population dynamics, harvest limits and monitoring the impact of the harvest on population trends.

Population Monitoring

The wild populations of both *C. porosus* and *C. johnstoni* have been monitored at varying levels of intensity since protection (Messel *et al*. 1981; Webb *et al*. 1984, 2000; Fukuda *et al*. 2011). The first surveys of Saltwater Crocodiles in tidal rivers were conducted in 1971 by Professor Harry Messel from the University of Sydney. His team introduced standardized spotlight surveys in tidal rivers in 1975 (Messel *et al*. 1981), and the standardization of the method has been maintained despite surveys being conducted by various institutions, giving consistent time-series data on population recovery. Furthermore, the same survey methods have been employed in some upstream, non-tidal rivers, containing mainly *C. johnstoni*.